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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656. 222.1]

Note on Train Speeds,

by Lionel WIENER,
Professor at the University of Brussels.

PART II *(Continued)* (1)

Train speeds and services in different countries.

XVIII. — SWEDEN.

SUMMARY.

CHAPTER XLIX.

1. General.
2. Track- and loading gauges.
3. The railway system. — The Railway Companies.
   Transverse lines.
   Alternative routes.
4. International lines and train ferries.
5. Traction.
   Electric traction.
   Turbine locomotives.
   Railcars.
6. Sleeping- and restaurant-car services *(Swedish State and Norwegian State Rys. and Mitropa Co.).*
7. Train speeds.
8. Conclusion.
9. Appendix. — The boat services.

CHAPTER XLIX.

XLIX-1. — **General.** — Some of the main lines of the Swedish system radiate from Stockholm, and others, in the extreme South of the country, run towards other capitals. The system is completed by some important transverse lines and a longitudinal one which runs parallel to the Scandinavian Alps and the frontier. There are thus three great longitudinal lines :

the furthest east, from Tralleborg to Nässjö, Stockholm, and Härnösand (1 111 km. = 690.3 miles) ;

the central one, from Göteborg to Hallsberg, Bräcke and Boden;

the western, from Göteborg to Östersund and Avidsjaur.

The cartogram of train speeds (fig. 326-Norway) shows clearly the main traffic currents — naturally differing on the longitudinal routes mentioned above — and table 294 gives details concerning them, and regarding long-distance runs covered at moderate speeds.

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(1) Cf. *Bulletin of the Railway Congress,* October and November 1933; January, May, June and July 1934; February, March, April, May, July and October 1935; March, May, June and July 1936.

XLIX-2. — **Track- and loading gauges** (fig. 327). — Unlike Norway, Sweden, from the beginning, adopted the standard gauge both for its main lines and a certain number of secondary ones. As in Norway, some of the latter, particularly in the South, were built to 1 067-m. (3′ 6″) gauge, but there is also a considerable extent of narrow-gauge lines, generally 0.891-m. (2′ 11 5/64″).

Whilst there are still some 500 km. (310 miles) of 3 ft. 6 in. gauge lines, 208 km. (129.3 miles) of which are operated by the *Blekinge-Kustbanor Co.* (1), the *Köping-Uttersberg-Riddarhyttan Ry.*, 59 km. (36.6 miles) long, is the only one to have been built to 1 093-m. (3′ 7″) gauge.

The narrow-gauge lines are owned by many companies, four of which operate more than 100 km. (62 miles), two more than 200 km. (124 miles), and two others more than 300 km. (186 miles) of railways (2). Here again, there is an un-

TABLE 288.

TRACK GAUGE.	4 ft. 8 1/2 in.	3 ft. 6 in.	3 ft. 11 in.
Loading gauge :			
Maximum height . m.	4.300 (14′ 1 5/16″)	3.600 (11′ 9 11/32″)	3.850 (12′ 7 19/32″)
— width . m.	3.400 (11′ 2 1/8″)	2.800 (9′ 2 1/4″)	2.650 (8′ 8 3/8″)
Constructional gauge :			
Maximum height . m.	4.800 (15′ 9″)	3.700 (12′ 1 11/16″)	4.000 (13′ 1″)
— — width . m.	4.240 (13′ 11″)	3.800 (12′ 5 5/8″)	3.600 (11′ 9 11/32″)

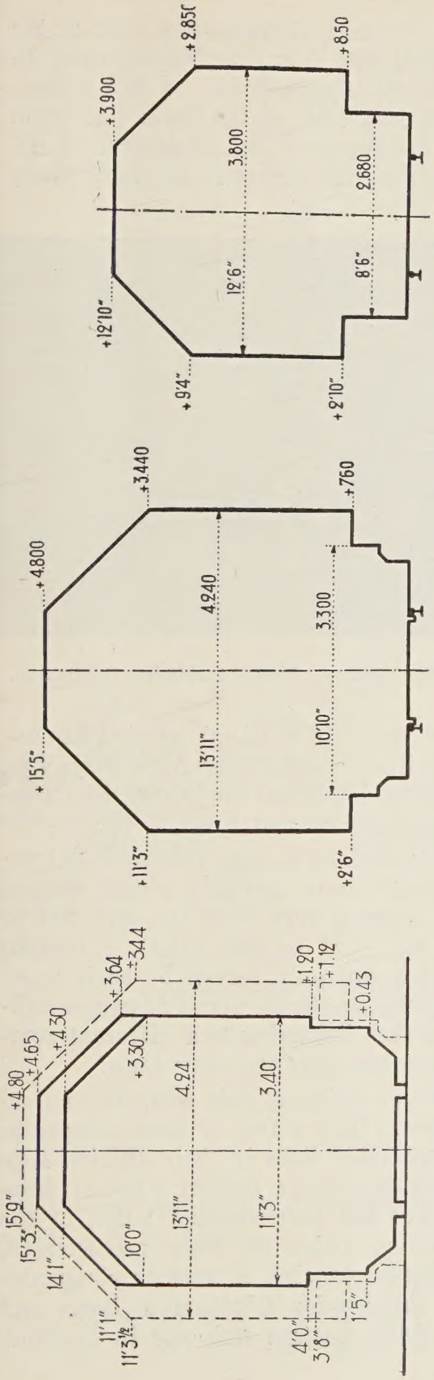
---

(1) Other 1 067 m. (3′ 6″) gauge lines are :

	Km.	Miles.
Växjo-Tingsryd	10	6.2
Halmstad-Bolmen	66	41.0
Hönshylte-Kvarnamäla	21	13.0
Karlshamn-Vislanda-Bolmen . .	29	18.0
Östra-Blekinge	65	40.4

(2) 2′ 11″ gauge railways :

	Km.	Miles.
Byvalla-Längshyttan	27	16.8
Dala-Ockelbo-Norrsundet. . . .	86	53.4
Falkenberg.	102	63.4
Gotland.	117	72.7
Hjo-Stenstorps	55	34.2
Kalmar-Berga	77	47.8
Kalmar-Torsäs	40	24.9
Kinnekule-Lidköping	29	18.0
Lidköping-Häkantorps.	28	17.4
Lidköping-Skara-Stenstorps . . .	50	31.0
Ljungbyholm-Karslunda	19	11.8
Mariestad-Moholm	18	11.2
Mönsteräs	70	43.5
Nordmark-Klarälvens	59	36.7
Do. electric . .	102	63.4
Norsholm-Västervik-Hultsfred . .	232	144.2
Öland.	151	93.8
Östergötlands smalspariga Jern .	316	196.4
Do. electric	71	44.1
Östra-Värend (Brittatorp-Älghultsby).	7	4.3
Stockholm-Roslagen	319	198.2
Do. electric	21	13.0
Uddevalla-Lelängen.	89	55.3
Västergötland-Göteborg	254	157.8
Växjö-Aseda-Hultsfred.	18	11.2
Vetlanda.	81	503



Gauge for 2' 11" track.

Gauge for 3' 6" track.

Gauge for 4' 8 1/2" track.

Fig. 327. — Loading gauges, *Swedish State Railways.*

usual gauge, 0.802-m. (2′ 7 5/8″) used on the 80 km. (50 miles) of the *Hällefors-Fredriksberg* (Säfnäs) *Ry.* and the 4 km. (2.5 miles) of the *Dalkarlsberg Ry.*

Finally there are 183 km. (113.7 miles) of 0.60-m. (1′ 11 1/2″) gauge line (¹).

The maximum loading gauges on standard 3′ 6″ and 2′ 11″ lines (fig. 327) are as shown in table 288.

XLIX-3. — Though the system is fairly dense south of the Gävle-Orsa line, particularly in the central Stockholm-Kil-Orsa region, and in the extreme South, in the Malmö-Hässleholm district, it thins down considerably north of Gävle-Orsa.

Although since the repurchase of some of the private lines, the *Swedish State* operates over half of the total railway system, i. e. 7 528 km. (4 677.7 miles), geographically the lines are very unequally distributed between the State and the private Companies. Thus, in the North, the relatively few railways north of Gävle all belong to the *State*. In order to link them up with its southern lines, it bought up on the 1st August two private railways — the Uppsala Gävle, 114 km. (70.8 miles) long and the Ostkustbanan, 320 km. (200 miles) — and it took on lease the 38 km. (23.6 miles) of the *Gävle-Ockelbo Ry.*

In spite of the dense railway network in the centre and South of the country,

---

(¹) 0.60-m. (1′ 11 5/8″) gauge railways :

Jönköping-Gripenberg . .	44 km. (27.3 miles).
Nattraby - Alnaryd - Almeboda	49 km. (30.4 miles.)

the system owned by the State is no more closely knit than in the North and is confined to the following main lines (fig. 330) :

Stockholm-Malmö-Trälleborg.
Stockholm-Laxa-Göteborg and Laxa-Charlottenberg (to Oslo) with a branch to Eskilstuna.
North to South transverse line from Mjölby to Alvesta and Ockelbo.

A few important connecting lines:

Norrköping-Katrineholm.
Nässjö-Falköping.
Hässleholm-Veinge.

Transverse line on the South-west coast, from Malmö to Göteborg with an extension to Strömstad, near the frontier.

The numerous other railways making up the system are privately owned, but unlike the practice followed elsewhere, the Companies own both main and secondary lines sometimes laid to standard, and elsewhere to narrow gauges. Some of them operate trunk lines, even sections of international routes, such as the *Dalsland Ry.*, from the Norwegian frontier to Mellerud (65 km. = 40.4 miles), which is a link of the main line from Oslo to Germany and Denmark. A similar situation occurs in Belgium, where the 61-km. (37.9 miles) of the Namur-Liége line, owned by the *Nord Belge Ry.*, forms an important section of the Paris-Berlin international line.

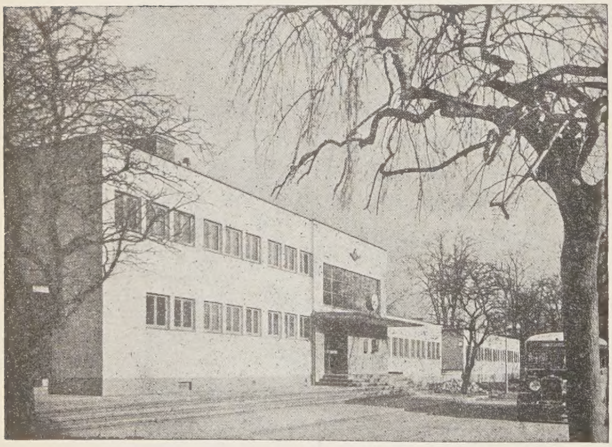


Fig. 328. — New Falkoping station, Göteborg line, *Swedish State Railways*.

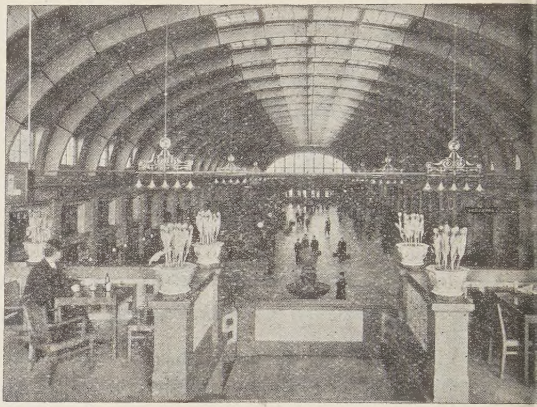


Fig. 329. — New Stockholm C. station.

It is curious to note that most private companies only operate a single railway line, often a very long one, say 200 to 400 km. (124 to 248 miles). Certain districts are only served by such lines, and two or three standard-gauge railways, each belonging to a different company, often serve the same town.

The evolution of this economic system is slow. Only a few of these companies operate other lines in their district. In a couple of cases, a further stage of development has been reached : that of the grouping, under the same management, of lines belonging to various companies like the *London Chatham & Dover* and the *South Eastern Railways* in England,

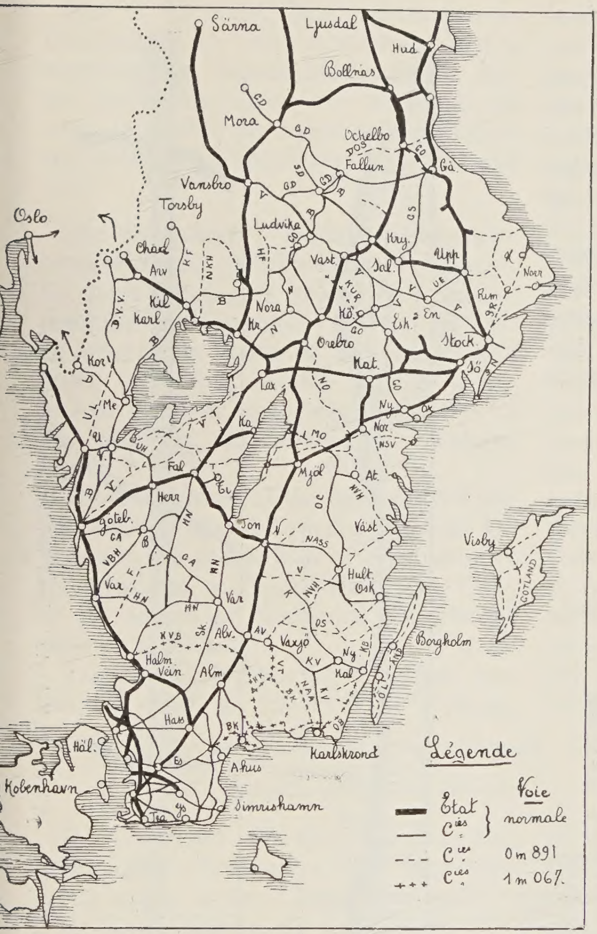


Fig. 330. — Aportionment of railways in central and southern Sweden between the *State* (heavy lines) and the private Companies.

Standard-gauge railways (North to South).

State Railways.
G.O. = Gävle-Ockelbo.
G.D. = Gävle-Dala.
G.S. = Gävle-Sala.
S.D. = Södra Dalarne.
B. = Bergslagernas Järnv.
V. = Stockholm-Västeras-Bergslagens Järnv.
U.E. = Uppsala-Enköping.
N. = Nora-Bergslags Järnv.
G.O. = Grängesberg-Oxelösund.
K.F. = Kil Fryksdalens Järnv.
D.V.V. = Dal-Västra-Värmlands Järnv.
D. = Dalslands Järnv.
U.H. = Uddevalla-Vänersborg-Herrljunga.
O.C. = Ostra Centralbanen.
Nass. = Nässjö-Oskarshamn.
H.N. = Halmstad-Nässjö.
G.A. = Göteborg-Boras-Alvesta.
A.V. = Alvesta-Växjö.
K.V. = Karlskrona-Växjö.
K. = Kalmar.

For extreme South, see fig. 335.

3 ft. 11 in. railways, unless stated otherwise.

D.O.N. = Dala-Ockelbo-Norrsundet.
S.R. = Stockholm-Roslagen.
K.U.R. = Köping-Uttersberg-Riddarhyttan (3' 7").
H.F. = Hällefors-Fredriksberg (2' 7 1/2").
N.K.H. = Nordmark-Klarälven-Hagfors.
N.O. = Norra-Östergötland.
N.V.H. = Norsholm-Västervik-Hultsfred.
U.L. = Uddevalla-Lelang.
V. = Västergotland-Göteborg.
F. = Falkenberg.
K.V.B. = Karlshamn-Vislanda-Bolmen (3' 6").
H.K. = Hönshylte-Kvarnamäla (3' 6").
V.T. = Växjö-Tingsryd (3' 6").
N.S.V. = Norrköping-Söderköping-Vikbolandet.
M.O. = Mellersta-Östergötland.
N.V.H. = Norsholm-Västervik-Hultsfred.
V. = Vetlanda.
O.S. = Östra-Smaland.
K.B. = Kalmar-Berga.
B.L. = Blekinge-Kustbanor (3' 6").
O.B. = Östra-Blekinge (3' 6").
N.A.A. = Nättraby-Alnaryd-Almeboda (1' 11 5/8").

Note : All State railways are built to standard gauge.

———	Private companies	Standard gauge.
— — — —		2' 11" gauge.
+ + + +		3' 6" gauge.

and more recently the *Paris-Orléans* and *Midi Rys.* in France.

The *Trafikaktiebolaget Grängesberg Oxelösunds Järnväg* is an instance. It consists of 300 km. (186 miles) of railways belonging to three different companies (fig. 330) :

The *Frövi-Ludvika Järnvägar ;*
The *Oxelösund-Flen-Västmanlands Järnvägar ;*
and the *Örebro-Köping-Järnvägar.*

It also operates the 4 km. (2.5 miles) of the *Stora-Gulsmedshyttan Ry.*

This Traffic Board is interesting from another point of view as well : it was the first to use a non-condensing turbine locomotive and the first to place further orders for this type of engine after its first trials.

A group of 0.891-m. (2′ 11 5/64″) gauge lines has also been formed. It is known as the *Östergöttlands Smalspariga Järnvägar* and operates the 387 km. (240.5 miles) of railways owned by the following companies :

The *Central Östergöttland,*
The *North Östergötland,*
The *Norsköping-Söderköping Vikbolandet,*
and the *Väderstad-Skännige Brännige.*

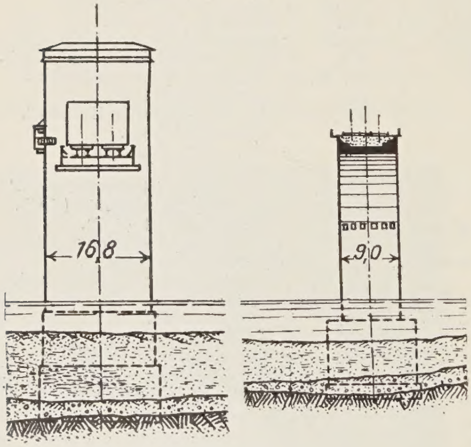


Fig. 331 (*). — Cross section of the Stockholm bridge.

Important private systems of very different character start from Gävle, Stockholm, Göteborg, Halmstad, Malmö, Ystad, Karlskrona and Kalmar.

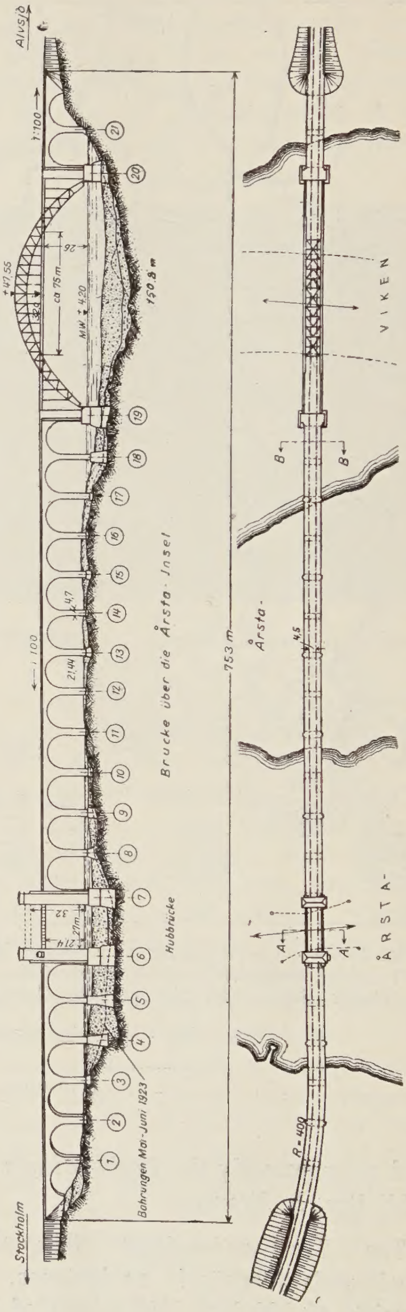


Fig. 332 (*). — Viken and Arsta Island bridge, in Stockholm.

(*) From *Organ für die Fortschritte des Eisenbahnwesens.*

Out of the eight lines radiating from Stockholm, two only, a northern and a southern one, belong to the *State;* they are linked up across the centre of the town (fig. 330) by means of an important bridge over the Viken (figs. 331 and 332).

The STOCKHOLM - VÄSTERÄS - BERGSLAGEN owns 413 km. (256.6 miles) of railways. Its main line, 298 km. (185.2 miles), reaching Ludvika and Vansbro, provides an alternative route of 621 km. (385.9 miles) instead of the 456 km. (283.3 miles) of the *State Rys.*, between Stockholm and Göteborg, via Kil instead of Falköping.

The importance of the 64-km. (39.7 miles) railway of the STOCKHOLM-NYNÄS Co. is due to the packet boat services between its terminus at Nynäshamn und Visby in the island of Gotland. The passage takes 7 1/4 hours.

The Stockholm northern private system, of 0.891 m. (2′ 11 5/64″) gauge, which belongs to the STOCKHOLM-ROSSLAGEN COMPANY, comprises 325 km. (202 miles) of railways, 21 km. (13 miles) of which are being electrified.

The GÄVLE-DALA RY's main line runs towards the Scandinavian Alps; it is 223 km. (138.6 miles) long as far as Älvdalen, but expresses only run as far as Rättvik. Other railway companies in the same district each built lines linking up the same places although only sometimes 20 miles apart only (figs. 330 and 333) (1).

The BERGSLAGERNAS JÄRNVÄG is an important Railway Company; its main line, from Göteborg to Kil and Falun, is 478 km. (297 miles) long. This Company runs its own sleeping cars, between Göteborg and Oslo, and restaurant cars, from Oslo to Malmö and from Göteborg to Ludvika. There is only one 8-km. (5 miles) branch to the town of Filipstad, lying to the West of the main line (2). On the other hand, this company leases the following private railways :

The *Dal Västra Värmlands Järnväg.*	182 km.	(113.1 miles),
the *Kil Fryksdalen Järnväg.* . . .	82 km.	(51.0 miles),
and the *Lödöse Lilla Edet Järnväg*	15 km.	(9.3 miles).

It has formed with the *Gävle-Dala* and *Södra-Dala Companies* an important group known as the « Bergslagen Route ».

In these districts, the important 0.891-m. (2′ 11 5/64″) gauge lines are those of the *Nordmark-Klarälven* (171 km. = 106.3 miles of electrified line) (3) and *Södra Dalarnes Järnväg* (134 km. = 83.3 mile) (4).

The Göteborg railway system is very

---

(1) The *Gävle-Dala Ry.* (29 km = 18 miles), joins Fulen and Repäken. Immediately to the South, are the 30-km. (18.6 miles) of the *Bergslagernas Järnväg.*

37 km. (23 miles) further South still, the position of Ludvika and Ställdalen, is very similar. These towns are linked up by the *Grängesberg-Oxelösund Ry.* (35 km. = 21.7 miles) and the *Bergslagernas Järnväg,* 35 km. (21.7 miles) long. In this case, the two lines starting from the same place end at the same town and cross each other on the way.

(2) Here again the railway is duplicated, as a line belonging to the State links up the same points.

(3) This railway is divided up as follows :

Filipstad West-Munkfors and branches.	102 km.	(63.4 miles).
Munkfors-Karlstad East	59 km.	(36.7 miles).
Karlstad East-Skoghall (steam traction)	10 km.	(6.2 miles).

(4) Expresses serve this 128 km. (79.5 miles) long line from Rättvik to Krylbo.

similar to the Stockholm one, and as with the latter two only of six radiating lines belong to the *State*. Three of the Companies owning the other railways are important (fig. 333) : particularly the BERGSLAGERNAS JÄRNVÄG and the VÄSTERGÖTLAND-GÖTEBORG JÄRNVÄG, the latter, a 254 km. (157.8 miles) long, 0.891-m. (2′ 11 5/64″) gauge railway. These Companies' lines run north following respectively the western and eastern banks of Lake Vanern. The third Company is the GÖTEBORG-BÖRAS-ALVESTA JÄRNVÄG with 221 km. (137.3 miles) of lines. There is a 132-km. (82 miles) extension belonging to the *Alvesta-Växjö* and *Växjö-Karlskrona Railways*, so that this route runs across the whole of the southern part of the peninsula from the Cattegat right to the Baltic (¹).

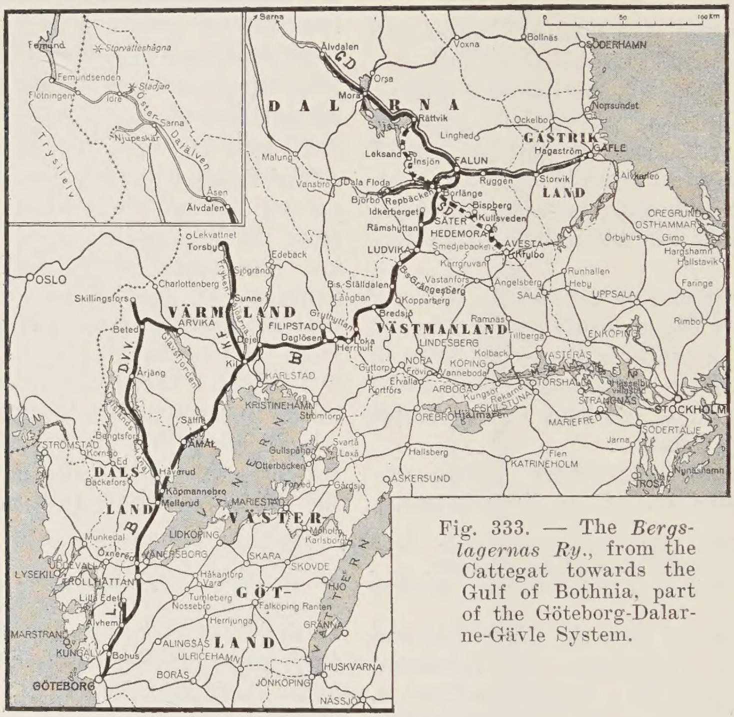


Fig. 333. — The *Bergslagernas Ry.*, from the Cattegat towards the Gulf of Bothnia, part of the Göteborg-Dalarne-Gävle System.

Legend :

B. ▬ = Bergslagernas Järnv.
K. F. ▬ = Kil Frijksdalen Järnv.
D. V. V. ▬ = Dal Västra Värmlands Järnv.
G. D. ═ = Gävle Dala Järnv.
S. D. - - - = Södra Dalarne Järnv.

(¹) The remaining important private railways in the district are :

Uddevalla-Vänersborg-Herrljunga Järnväg . .	92 km.	(57.2 miles).
Varberg-Boras-Herrljunga	127 km.	(78.9 miles).
Skäne-Smalands Järnv.	150 km.	(93.2 miles).
Kalmar Järnv. (*)	195 km.	(121.2 miles).
Linköping-Hultsfred *(Östra Centralbanan)* . .	123 km.	(76.4 miles).
Östra-Skanes Järnv.	173 km.	(107.5 miles).

(*) Besides this Company, two others serve Kalmar : the *Kalmar Berga* [with a 77 km. (47.8 miles) 2′ 11″ line] and the *Kalmar-Torsas* [with 40 km. (25 miles) to the same gauge].

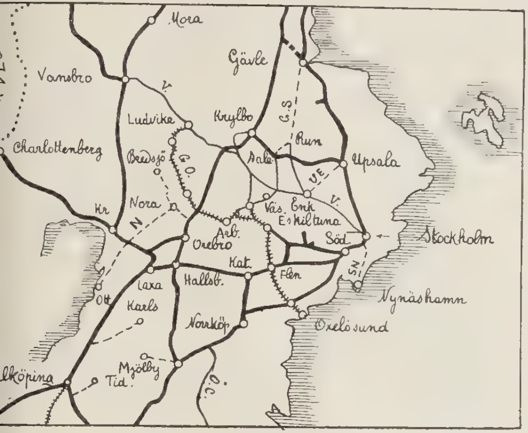


Fig. 334. — Standard-gauge railways west of Stockholm, belonging to the State (heavy lines) and to private Companies.

Legend :

G. O. = Grängesberg-Oxelösund Järnv.
G. S. = Gävle-Sala Järnv.
N. = Nora-Bergslagen Järnv.
S. N. = Stockholm-Nynäs Järnv.
Ö. C. = Östra Centralbanan Järnv.
V. = Stockholm-Västerås-Bergslagen Järnv.

The 411 km. (255.4 miles) of the HALMSTAD-NÄSSJÖ Co. comprise two main lines, the Halmstad-Nässjö (196 km. = 121.8) and the Halmstad-Falköping (190 km. = 118.1 miles) (¹), and a few branches.

In the extreme southern part of the Skåne province, there are a series of ports : Hälsingborg, Landskrona, and Malmö in the West ; Trälleborg, and Ystad in the South ; Simrishamn and Ahus (for Kristianstad) in the East. The way the system has been divided up between the *State* and private Companies is also quite characteristic (fig. 335). Apart from a few branches, the only railway operated by the *State* runs from Trälleborg to Malmö, where it splits up into two branches, the first continuing to Stockholm and the other to Angelholm (Göteborg).

All other railways are privately owned and in several instances, some of these lines have been almagamated for joint operation. Certain lines, such as the Malmö-Trälleborg (section of the Malmö-

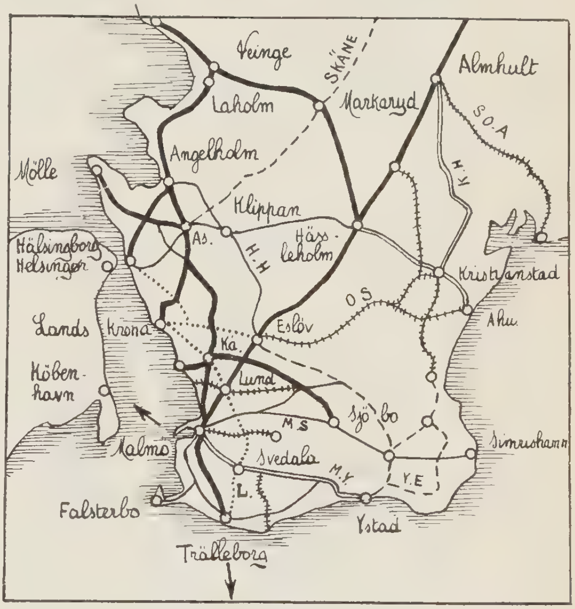


Fig. 335. — Standard-gauge railways in the province of Skåne, belonging to the *State* (heavy lines) and to private Companies.

Legend :

H.H. = Hälsingborg-Hässleholm.
K.H. = Kristianstad-Hässleholm.
L. = Landskrona och Hälsingborg.
M.S. = Malmö-Simrishamn.
M.Y. = Malmö-Ystad.
O.S. = Östra-Skånes.
S O.A. = Sölvesborg-Olofström-Älmhult.
Y.E. = Ystad-Eslöv.

(¹) The Halmstad-Bolmen [66 km. (41 miles) 1 067-m. (3′ 6″) gauge] and the Nässjo-Oskarshamm Railways (149 km. = 92.6 miles, standard gauge) belong to different companies.

Simrishamn Company) duplicate the *State* line (32 instead of 30 km = 20 instead of 18.6 miles). Others such as the ***Hälsingborg-Hässleholm*** and ***Malmö-Ystad*** lines complete services to the international ports and the latter provides the quickest route between Denmark and its Island, Bornholm.

Malmö is served by the following companies :

	Km.	Miles.
Malmö-Simrishamm (1)	207	128.6
Malmö-Ystad	63	39.1
Malmö-Genarp	28	17.4
Ystad-Eslöv	76	47.2
Do. works the Ystad Brösarp .	30	18.6
Do. works the Ystad St. Ölof .	43	26.7

In the North-West there are three other companies :

	Km.	Miles.
Landskrona-Lund-Trälleborg . .	74	45.9
Landskrona-Hälsingborg (and Eslöv)	60	37.3
Hälsingborg-Hässleholm (2) . .	149	92.6

And in the North-East :

	Km.	Miles.
Östra-Skäne	173	107.5
Östra-Blekinge	65	40.4
Östra-Centralbanan.	123	76.4
Kristiansand-Hässleholm. . . .	116	72.1

Finally it should be added that the insular systems are built to the 0.891-m. (2′ 11 5/64″) gauge. Oland has 151 km. (93.8 miles) and Gotland 117 km. (72.7 miles) of railways; on the other hand, Bornholm (Denmark) has 118 km. (73.3 miles) of 1 067-m. (3′ 6″) gauge lines.

TRANSVERSE LINES. — Several of the transverse lines carry much traffic and are worthy of more than passing mention.

The Trälleborg and Hälsingborg train ferries are links in the international services towards Stockholm, as well as towards Göteborg and Oslo. Although a radiating Norwegian line, this latter line is also an international transverse Swedish one in the same way as the Calais-Basle railway is at the same time a London radiating and a French transverse line.

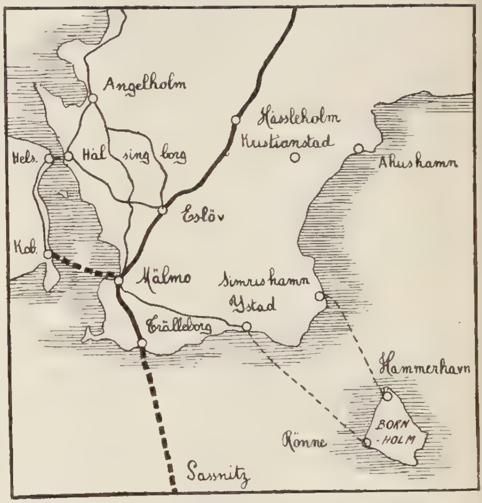


Fig. 336. — International lines in south-western Sweden showing the Copenhagen- Bornholm land-and-sea route.

Another very interesting transverse service maintained through Swedish territory during the Summer months, provides the quickest connection between Copenhagen and the Danish island of Bornholm, which is separated from the Danish capital by the southern portion of the Swedish peninsula (fig. 336). This through line is made up of a ferryboat crossing from Copenhagen to Malmö (29.7 km. = 18.5 miles), a railway section from Malmö to Ystad (63 km. = 39.1 miles), and finally a sea route from Ystad to Rönne (Bornholm).

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(1) Unlike most others, this Company works a system made up of five lines :

Malmö-Simrishamn;
Dalby-Bjärsjölagard;
Malmö-Trälleborg;
Trälleborg-Rydsgard;
Vellinge-Skanör-Falsterbo.

(2) Including the following lines :

Klippan-Eslöv;
Ängelholm-Klippan;
Bjur-Billesholm.

ALTERNATIVE LINES (fig. 330). — Only exceptionally are expresses between the same places run over different routes; thus through trains from Stockholm to Malmö are generally run over the direct Jarna (47th/km. = 29th mille), Nyköping Aby (155th/km. =96th mile) and Norrköping (163rd km. = 101st mile) line, but some of them are diverted by the Göteborg line as far as Katrineholm (125th km. = 77th mile) and join the former route at Aby (165th km. = 103rd mile). The distance between Jarna and Aby ist 108 km. (67 miles) via Nyköping and 126 km. (78 miles) via Katrineholm.

XLIX-4. — International lines and train ferries. — Connections between Sweden and each of her neighbours —

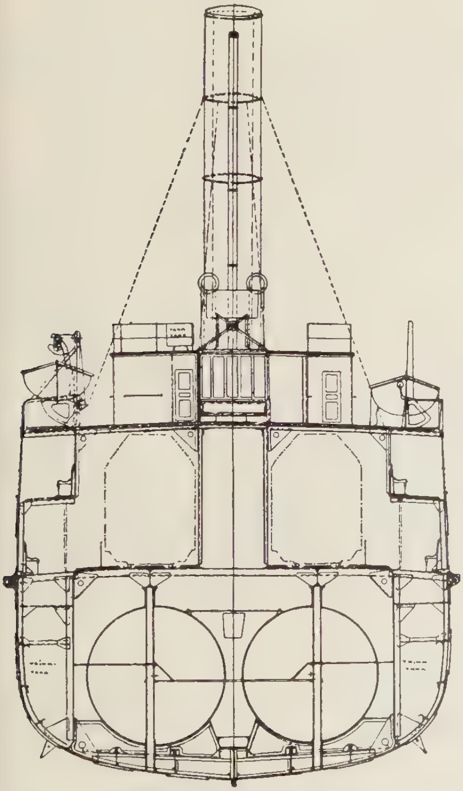

Fig. 337. — Cross section of the two-track, train ferry « Drottning Victoria », showing the loading gauge.

Swedish State Railways.

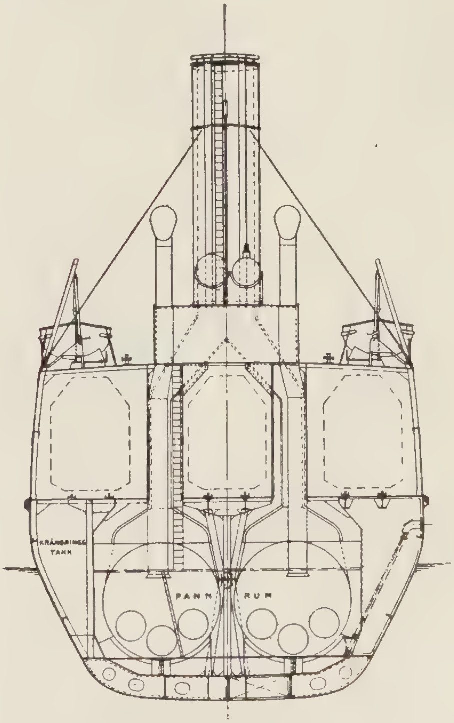

Fig. 338. — Cross section of the three-track train ferry « Stärke », showing the loading gauge.

Swedish State Railways.

Finland, Norway, and the Continent — differ essentionally from each other.

Although the Swedish trains cross the Tornea, the frontier river, near its mouth, by means of a 405-m. (1 329′) long bridge between Haparanda and Tornea, they do not proceed beyond, and owing to the difference of gauge, there is no direct railway communication between Sweden and the interior of Finland (fig. 339).

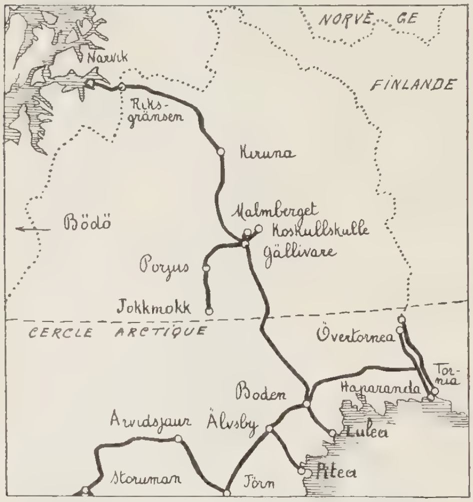

Fig. 339. — Lapland Railway and parallel railway lines on both sides of the Swedish-Finnish frontier.

On the other hand, the relations between Sweden and Norway are very close and often peculiar (fig. 326). In the extreme North, as well as in the middle of the peninsula, Sweden has free from ice outlets to the Norwegian ports of Narvik and Trondheim.

The Narvik line is 479 km. (297.6 miles) long from Lulea (46 km. = 28.6 miles being in Norway) and brings Narvik within 1 581 km. (982.4 miles) of Stockholm.

The second line of this kind reaches the Norwegian port of Trondheim, 63°30′ North, and also crosses the Scandinavian Alps. This is the inlet towards a Swedish line proceeding to Tovmodalen (93rd km. = 58th mile) and Storlien [106th km. (66th mile), 593 m. (1 945′) above sea level] in Norway, and then on to Änge and the Swedish port of Sundsvall, 465 km. (289 miles) from Trondheim. By this route, the distance to Oslo is 553 km. (343 miles).

In the South, the international connections with Oslo are very different. The

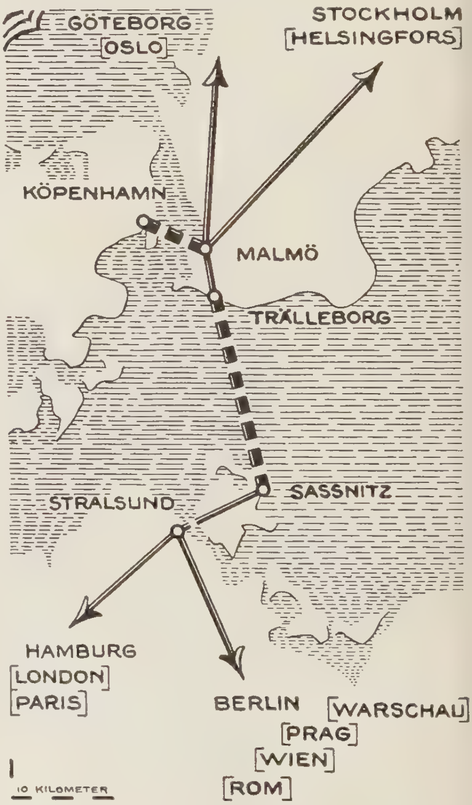

Fig. 340. — Train ferry services between Sweden and the Continent.

line from Stockholm to Oslo is not remarkable in any way. It is 573 km. (356 miles) long altogether, 431 km. (267.8 miles) of which as far as Charlottenberg being in Sweden.

The international lines in the South have other points of interest as, owing to the geographical form of this part of Europe, they are mixed rail-and-sea routes, on which train ferries have long ago been introduced. They comprise the following sea crossings (fig. 340) :

a) Germano-Swedish line, from Trälleborg to Sassnitz	107 km.	(66.5 miles).
b) Swedish-Danish line form Malmö to Copenhagen.	29.7 km.	(184.6 miles).
c) Danish line from Hälsingborg to Helsingör. . .	5.1 km.	(3.2 miles).

They not only link up Germany and Denmark with Sweden, but also those with Norway, via the southern part of Sweden, and provide the quickest services between Denmark and the Island of Bornholm. They are the outcome of action taken by Denmark. In 1903, upon the Wärnemunde-Gjedser steam packets were purchased and train ferries run in their stead. This was found profitable and part of the Germano-Scandinavian traffic was diverted from the direct to the new ferry route. In order to fight this competition the German and Swedish Governments decided to do the same and to turn their Sassnitz to Trälleborg sea route into a train ferry service and this in spite of the fact that it was 107 km. (66.5 miles) long.

The new service, started on the 6th July 1909, was chiefly intended for passenger traffic, but goods traffic soon became important. In spite of the decline in traffic due to the War, its progress was just as rapid as that of the Swedish-Danish Copenhagen-Malmö line, while the Warnemünde train ferry was only able to reach its formel level.

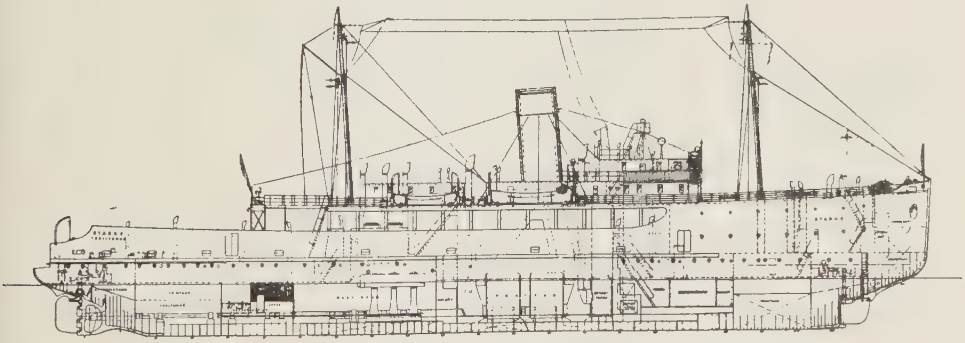

Fig. 341. — The train ferry « Stärke ».

Traffic in both directions is irregular, and in the proportion of 7 to 5 in the case of Swedish exports and imports via Trälleborg, whereas this is 3 to 1 in the case of exports and imports via Gjedser and 5 to 1 for exports and imports via Malmö.

The following table gives the time taken by the crossing, together with the total time spent embarking and landing the trains in the harbours .

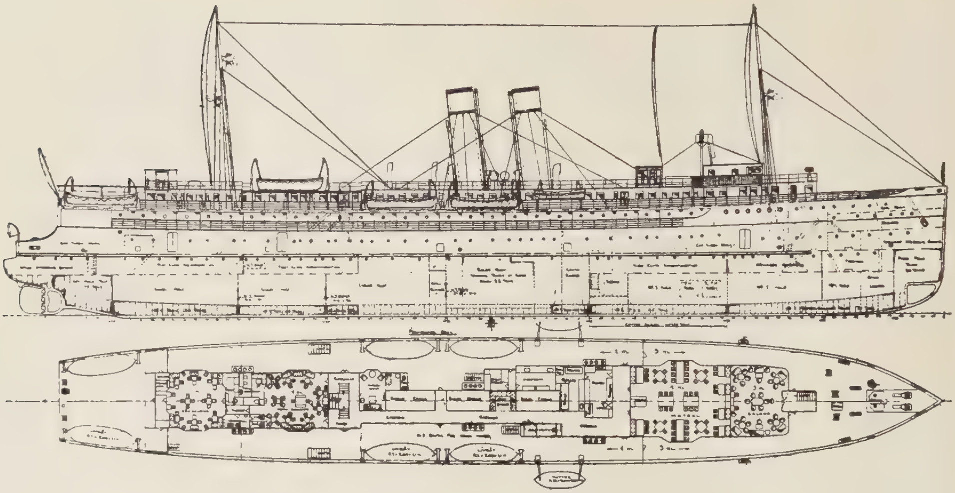

Fig. 342. — The train ferry « Drottning Victoria ».

TABLE 289.

SWEDISH TRAIN FERRY SERVICES.

PASSAGE.	Distance.		Track capacity.		Time spent.		
	Km.	Miles.	M.	Feet.	Train onto ferry.	Crossing.	Train off ferry.
Trälleborg-Sassnitz . . .	107	66.5	168	551	0.28	4.10	0.30
Malmö-Copenhagen. . . .	30	18.6	147	392	0.10	1.30	0.10
Hälsingborg F.-Helsingör .	5	3.2	66	$216^{1}/_{2}$	0.20	0.22	0.20

TABLE 290.

TRAFFIC HANDLED BY THE SWEDISH TRAIN FERRY SERVICES.

MALMÖ-COPENHAGEN SERVICE.				TRÄLLEBORG-SASSNITZ SERVICE.			
YEAR.	Number of			YEAR.	Number of		
	Crossings.	Passengers.	Tons of goods.		Crossings.	Passengers.	Tons of goods.
1900	2221	39 079	125 307	1910	1739	71 094	72 927
1914	3462	80 732	242 432	1914	2211	129 283	129 715
1915	4612	45 114	434 931	1916	2452	26 961	333 703
1921	1643	53 553	86 099	1919	1315	46 783	63 089
1930	3093	198 339	212 012	1930	3028	165 365	239 997
1934	...	241 165	123 674	1934	...	109 549	191 370

In 1934, the Helsingör-Hälsingborg line carried 644 346 passengers and 96 582 tons of goods.

The number of vehicle-axles, which totalled 180 765, was contributed by the three services as follows :

Helsingör-Hälsingborg. .	44 570, i. e. 24.5 %.
Trälleborg-Sassnitz . . .	90 859, i. e. 50.3 %.
Malmö-Copenhagen . . .	45 336, i. e. 25.2 %.

XLIX-5. — **Electric traction.** — So as not to depend on coal import, the *Swedish State Railways* have called upon their enormous reserves of water-power, and have gradually electrified their system, using single-phase 15 000-volt 16 2/3-cycle current. Out of a total of 7 449 km. (4 628.7 miles), 2 141 km. (1 330.4 miles) i. e. 28 %, or 12.9 % of the total railway system has already been electrified, and 3 000 km. (1 864 miles) more will have been added by the end of 1937. This 31.2 % of the country's railway system covers lines which carry 80 % of the total traffic.

In addition some, 285 km. (177.1 miles) of private railways are also electrified.

The LAPLAND RAILWAY which lies beyond the Arctic Circle, and is one of the most remarkable in the country, was wisely chosen to experiment upon (fig. 339).

Its construction was considered as early as 1877, in order to assure the transport of the great mineral resources of the region and be able to ship them either at the Swedish Baltic port of Lulea, or the Norwegian Atlantic port of Narvik, which is never ice bound. This transverse line was to be built quite apart from the rest of the system; it was to run right across the peninsula and through the Scandinavian Alps near Riksgränzen on the frontier.

In 1883, the *Northern of Europe Railway Co.* an Anglo-Scandinavian concern, obtained the concession which, in 1886, it passed on to the *Swedish and Norwegian Ry. Co.*, in which Dutch interests predominated.

The country run through is pratically uninhabited, and one of the coldest in the world, and four mountain ranges had to be crossed in succession. Maximum 1 in 100 gradients rule over a great part of the line, the maximum altitude of which is 551 m. (1 808′) between Gällivare (359 m. = 1 178′), and Kiruna (502 m. = 1 647′ above sea level). It then falls all the way to the Atlantic, Riksgränsen (frontier station) (433rd km. = 269th mile) being at 521 m. (1 710′) above sea level, which is reached in Norway 46 km. (28.6 miles) beyond, at Narvik, at a distance of 479 km. (297.6 miles) from Lulea.

Both North and South of the line, the Alps rise to over 2 000 m. (6 560′) above sea level (¹), except immediately South of the railway where the highest peaks are somewhat lower [the Njulja on the bank of the Tornetrask is only 1 199 m. (3 933′) above sea level].

Besides the cold and the absence of inhabitants, other difficulties had to be contended with, particularly those occurring from snow, which caused considerable trouble. In spite of this, the 168-km. (104.4 miles) stretch from Boden to Gällivare was opened to traffic in 1887. This was the end of the original undertaking as financial difficulties prevented the completion of the line; the two

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(¹) The Akavare, in the North, reaches 2 013 m. (6 604′) above sea level; a little south of this, the Kebnekaise rises to 2 123 m. (6 965′), and further on the Sarektjakko to 2 090 m. (6 857′).

Governments concerned therefore took over the concessions in 1891. However work was not really resumed until 1898; the old line was then rebuilt, the location improved, the permanent way strengthened, and construction of the new part of the line pushed on.

The electrification on 16 000 volts, 15 cycles, of the 129 km. (80.2 miles) from Kiruna to the frontier (Riksgränsen) begun in 1910, was completed before the War. Results having come up to expectations, it was decided, in 1916, to electrify the rest of the line, from Kiruna to the gulf of Bothnia.

In 1917, the 147 km. (91.3 miles) from Kiruna to Nattavara were taken in hand, and by 1921 the last section from Nattavara to Lulea was dealt with so that end to end electric operation was started in 1922. Electrification of the Norwegian section was immediately proceeded with, and this in turn was electrically operated from the following year.

OTHER ELECTRIC RAILWAYS. — Since 1922, main-line electrification has been undertaken with 15 000-volt, 16 2/3-cycle instead of 16 000-volt current, as on the earlier line. The 459 km. (285.2 miles) from Stockholm to Göteborg were first electrified, soon to be followed by the 630 km. (391.5 miles) from Stockholm to Malmö und Trälleborg, the 299 km. (185.8 miles) from Göteborg to Malmö, some transverse lines, and the first section (Stockholm to Krylbo, 323 km. = 200.71 miles) of the Stockholm-Änge-Storlien and Trondheim line.

The present position of the *Swedish State Railways'* electrification is shown below. Lines in course of electrification or to be electrified are shown in italics.

RAILWAY.	Km.	Miles.	—
Lulea-Riksgränsen (Narvik)	433	269.1	
Stockholm-Krylbo (Trondheim)	161	100.0	
Krylbo-Ange	*323*	*200.7*	Work in progress.
Ange-Storlien (Trondheim)	*264*	*164.0*	Electrification projected.
Stockholm-Järna-Göteborg	456	283.3	
(Stockholm) Järna-Malmö	557	346.1	
TRANSVERSE LINES.			
Katrineholm-Norrköping	48	29.8	North to South transverse line.
(Änge) Krylbo-Orebrö-Mjölby	253	157.2	Do.
Nässjö-Falköping	113	70.2	East to West transverse line.
Hässleholm-Veinge (Göteborg)	*72*	*44.7*	Electrification in progress.
Astorp-Mölle	*37*	*23.0*	
Hälsingborg-Angelholm (Göteborg)	*126*	*78.3*	
Göteborg-Mellerud-Kornsjö (Oslo)	*188*	*116.8*	Electrification projected.
Göteborg-Strömstad	*181*	*112.4*	

The Malmö-Göteborg line is electrified as far as Halmstad. During the year, the following lines are to be electrified as well :

Laxa-Charlottenberg;
Södertalje-Eskilstuna;
Uppsala-Gävle;
and about 100 km. (62 miles) of branches.

All the electric locomotives have coupling rods and their maximum axle load is 17.5 t. (17.2 Engl. tons). After having gained experience with the first two types of passenger locomotive used on the *Lapland Railway,* a 1-C-1 locomotive to haul 550-ton passenger trains at a speed of 90 km. (56 miles) an hour, or 900-ton goods trains at 70 km. (43.5 miles) an hour was gradually evolved for the newly electrified Stockholm-Göteborg line.

TABLE 291.
SWEDISH ELECTRIC LOCOMOTIVES.

—	Type	Date	Horse-power
2-B-2	Pa.	1914	900
1-C-C-1	Oab.	1914-1916	1 600
B-B	Oc.	1919	1 000
D	Od.	1920	1 130
2-B-B-2	Pb.	1922-1927	2 900
1-C-C-1	Oef.	1925-1930	1 660
1-C-1	D.	Do.	700
C	Vab.		

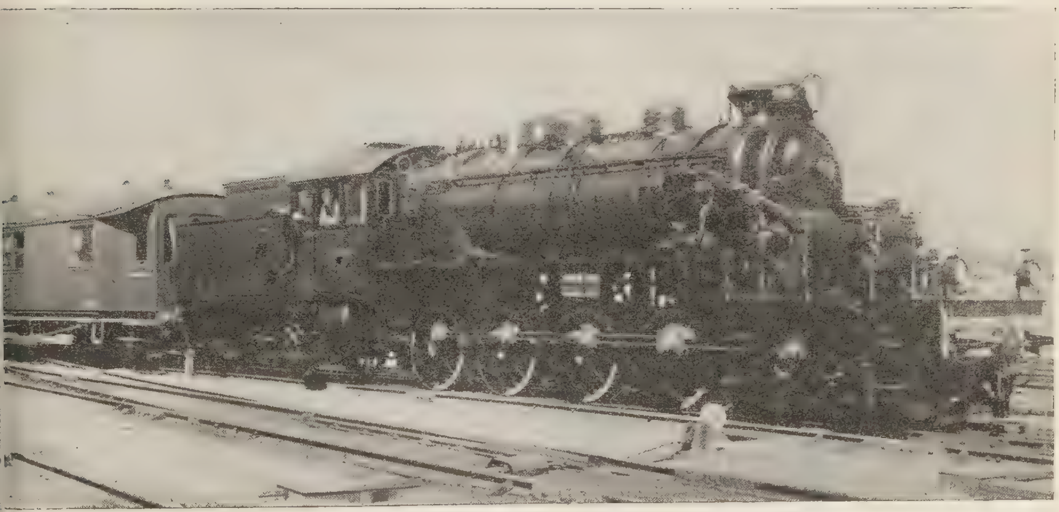

Fig. 343. — Non-condensing turbine locomotive, Grängesberg-Oxelösund Railway.

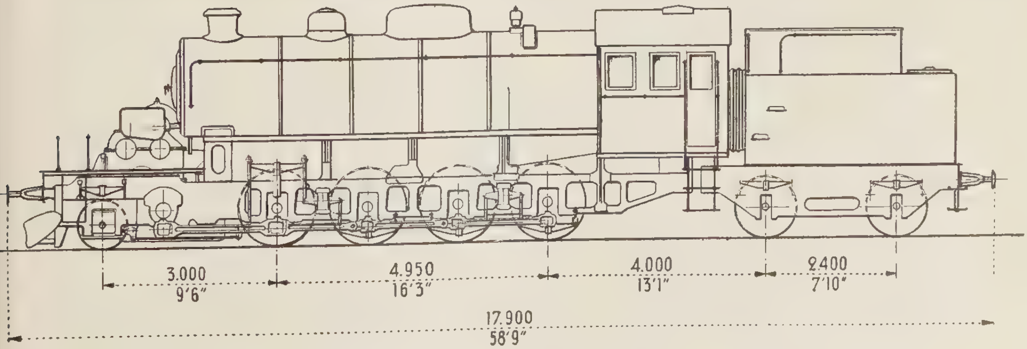

Fig. 344. — Elevation of turbine locomotive (fig. 343).

TABLE 292.

LEADING DIMENSIONS OF SWEDISH TURBINE LOCOMOTIVES.

Date built Railway	1921 Swedish State.	1923 Argentine State (1).	1926. L. M. S. (2).	1927. Swedish State.	1932 and 1936. Grängesberg-Oxelösund Co.
Maximum tractive effort . . . tons	12	15.0	18	14.56	20
Normal maximum speed, km. (miles) p. h.	60 (37.3)	40.8 (25.4)	75 (46.6)	55.9 (34.7)	60 (37.3)
Length, overall . . . m. (ft. in.)	21.95 (72′)	21.35 (70′)	22.50 (73′ 11″)	22.80 (75′)	17.90 (58′ 9″)
Wheel diameter, driving . . . m. (ft. in.)	1.39 (4′ 6″)	1.47 (4′ 10″)	1.60 (5′ 3″)	1.58 (5′ 2″)	1.35 (4′ 5 5/32″)
Wheel diameter, carrying . . . m. (ft. in.)	...	...	1.52 (5′)	...	...
Total wheel base . . . m. (ft. in.)	...	...	19.20 (63′)	...	14.35 (47′ 1″)
Boiler pressure . . . kgr./cm² (lb. p. sq. in.)	21 (300)	19.68 (280)	17.6 (250)	20 (284)	13 (185)
Grate area . . . m² (sq. ft.)	2.60 (28)	...	2.80 (30)	3.06 (31.2)	3 (32.3)
Heating surface, firebox . . . m² (sq. ft.)	10.03 (108)	11.98 (129)	13 (140)	...	...
Heating surface, total . . . m² (sq. ft.)	104.97 (1 130)	99.95 (1 076)	148.64 (1 600)	135.90 (1 463)	149.2 (1 606)
Heating surface, superheater . . . m² (sq. ft.)	80.70 (861)	57.41 (618)	59.45 (640)	74.97 (807)	100 (1 076)
Heating surface, feed heater . . . m² (sq. ft.)	165 (1 787)	798 (8 600)	...	...	...
Horse-power (turbine) . . .	1 800	1 750	2 000	2 000 (at 75 m. p. h.)	...
Turbine speed at 100 km. (62 miles) an hour, r.p.m.	9 200	...	10 500	10 000 (at 56 m. p. h.)	1 270 (at 25 m. p. h.)
Cooling surface of condenser . . . m² (sq. ft.)	1 000 (10 760)	2 015 (21 700)	...	1 347 (14 500)	...
Thermal efficiency, total . . .	14.7 %	...	...	...	...
Fuel carried, oil . . . kgr. (lb.)	...	6 485 (14 300)	...	...	...
Fuel carried, coal . . . tons	7	...	6	7.38	5
Weight, adhesive . . . tons	48	56.6	...	48.72	70.9
Weight, condenser vehicle . . . tons	64	68.9	73.9	77.75	...
Weight, boiler vehicle . . . tons	62	61.0	69.8	76.75	115.6
Weight, total, in working order . . . tons	126	129.9	143.7	154.5	90.1
Weight, total, empty . . . tons	...	108.0	...	...	...
Track gauge . . .	Standard	Metre.	Standard	Standard	Standard

(1) Built in Sweden.

(2) Built in England, under licence, by *Metropolitan Vickers*. Quoted for comparison.

Traction by turbine locomotives. — Several Ljugström locomotives all built by *Nydquist & Holm Ltd.* have been acquired both by the *Swedish State Rys.* and by a private Company.

The *State Railways'* Condensing locomotives. — In 1924, the first of these locomotives was put into service on local and express trains, and hauled 300-ton trains between Stockholm and Göteborg (¹).

Non-condensing locomotives of the *Grängesberg-Oxelösund Ry.* (figs. 343 and 344). — The first of these locomotives was purchased in 1932: two others are on order. In the case of locomotives of a certain power (2 000 h.p. and upwards) their cost is about the same as that of piston locomotives and the saving in fuel is said to be about 23 %.

They haul ore trains, which usually weigh about 1 750 tons, between Eskilstuna and the port of Oxelösund. Their maximum speed is 70 km. (43.5 miles) (only 60 km. = 37.3 miles on the section in question); their effective overall speed is 30 to 40 km. (18.6 to 25 miles) an hour (²).

Railcars. — Like the *State Railways*, the private Companies operate diesel railcars, the first of which, built by the A.S.E.A., were put into service in 1912.

XLIX-6. — **Sleeping- and restaurant-car services** *(fig. 345)*. — Although the *International Sleeping-Car Co.* does not operate in Sweden, there are a number

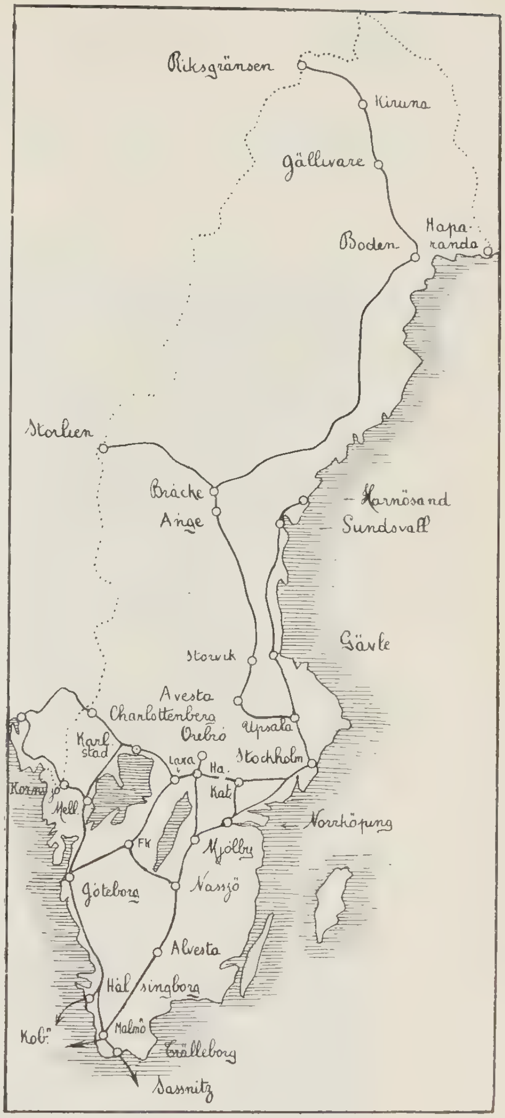

Fig. 345. — Swedish sleeping-car services.

(¹) The *Nydquist & Holm Works* built an oil-fired turbine locomotive for the metre-gauge *Argentine State Rys.* at the same time. Power : 1 750 h.p. Radius of action : 800 km. (500 miles) in 20 hours without refuelling.

(²) The L. M. S. non-condensing passenger locomotive, built by *Metropolitan Vickers*, develops 2 000 h.p.

The leading dimensions of the Swedish turbine locomotives are given in table 292.

of sleeping- and restaurant-car services belonging to several railway administrations.

The greater number are those of the *Swedish State Rys.*, whose rolling stock is unsurpassed by any other (fig. 346 to 349).

The *State Rys.* were among the first, it should also be remembered, to introduce 3rd-class sleepers with three superposed berths, which ran in 1910, shortly after the similar Norwegian Christiania (Oslo) and Bergen services, between Stockholm and Göteborg (457 km. = 284 miles).

In 1912 the Stockholm-Lulea service (1 176 km. = 730.7 miles) was introduced and in 1913 a service between Stockholm and Malmö was advertised, when the decline in the use of these carriages led the Administration to withdraw them. More comfortable stock with 15 three-berth (instead of 8 six-berth) compartments, i. e. a total of 45 only (instead of 48) (fig. 346) were provided and have proved successful.

The charge for the use of the sleeping-cars does not depend upon the distance, as in other parts but is 20, 10 or 5 kr. a night, according to the class. This system is a logical one on sleeping-cars belonging to the railway Companies, the ordinary ticket already taking the distance into account.

The second-class sleeping cars only differ from the first-class in that they have two berths, and the latter one only per compartment.

Thanks to the generous loading gauge it was possible to build most comfortable vehicles (fig. 347), whose leading dimensions are as follows :

TABLE 293.

LEADING DIMENSIONS OF SWEDISH SLEEPING- AND DINING CARS.

TYPE OF VEHICLE.	Sleeping car.	Dining car	2nd-class.
Length overal . . . . .m. (ft. in.)	23.500 (77′ 1″)	21.300 69′ 10 5/8″)	23.500 (77′ 1″)
— of body. . . . . .m. (ft. in.)	22.200 (72′ 10″)	20.000 65′ 7 7/16″)	22.200 (72′ 10″)
Outside width . . . . .m. (ft. in.)	3.135 (10′ 3 7/16″)	3.135 (10′ 3 7/16″)	3.135 (10′ 3 7/16″)
Height. . . . . .m. (ft. in.)	4.000 (13′ 1 15/32″)	4.080 (13′ 4 5/8″)	4.080 (13′ 4 5/8″)
Bogie wheelbase . . . . .m. (ft. in.)	3.600 (11′ 9 25/32″)	2.400 (7′ 10 15/32″)	3.600 11′ 9 25/32″)
Distance between bogie centres. . .m. (ft. in.)	16.000 (52′ 6″)	15.000 (49′ 2 1/2″)	16.000 (52′ 6″)
Wheel diameter . . . . .m. (ft. in.)	0.984 (3′ 2 3/4″)	0.984 (3′ 2 3/4″)	0.984 (3′ 2 3/4″)
1st/2nd-class compartments	7	40 seats.	2 (2nd)
3rd-class —	5	—	48 passengers.
Tare . . . . Metr. (Engl.) tons.	52.4 (51.4)	44.4 (43.7)	46.2 (45.5)

All-Swedish sleeping-car services are run between :

Stockholm and Härnösand. Riksgränsen (for Narvik), Änge as well as Stockholm and Storlien (Trondheim), Göteborg, Alvesta, and Karlskrona;

On the tranverse line, from Orebro, via Alvesta, to Malmö.

International services comprise those :

From Stockholm to Copenhagen, as well as to the Swedish ports of Hälsingborg, Malmö, and Trälleborg;

Also to Hamburg, and Berlin.

Excluding ferryboat mileage, these services cover a total of 2 937 km. (1 825 miles) of lines.

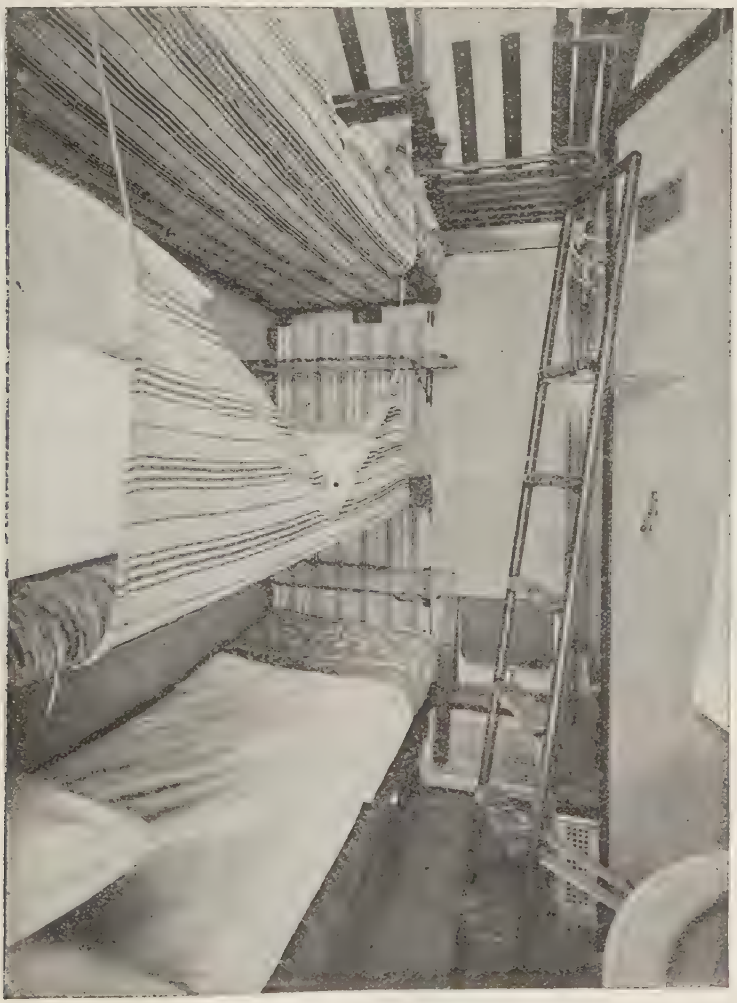

Fig. 346. — Third-class sleeping-car compartment with three superposed berths.

Swedish restaurant cars are run between :

Stockholm, Alvesta and Göteborg;
Laxa and Karlstad;
Stockholm, Boden, Änge and Härnösand;
Göteborg and Malmö.

NORWEGIAN SERVICES IN SWEDEN. — The close relations between Sweden and Norway have led to some of these services being duplicated between Oslo and Stockholm by the *Norwegian State Rys'* sleeping-car services.

The MITROPA sleepers run from Trälleborg to Berlin and Hamburg, using the Sassnitz ferryboat. On these routes the German rates of 25 or 12.50 Rm. a night in 1st or 2nd-class are charged.

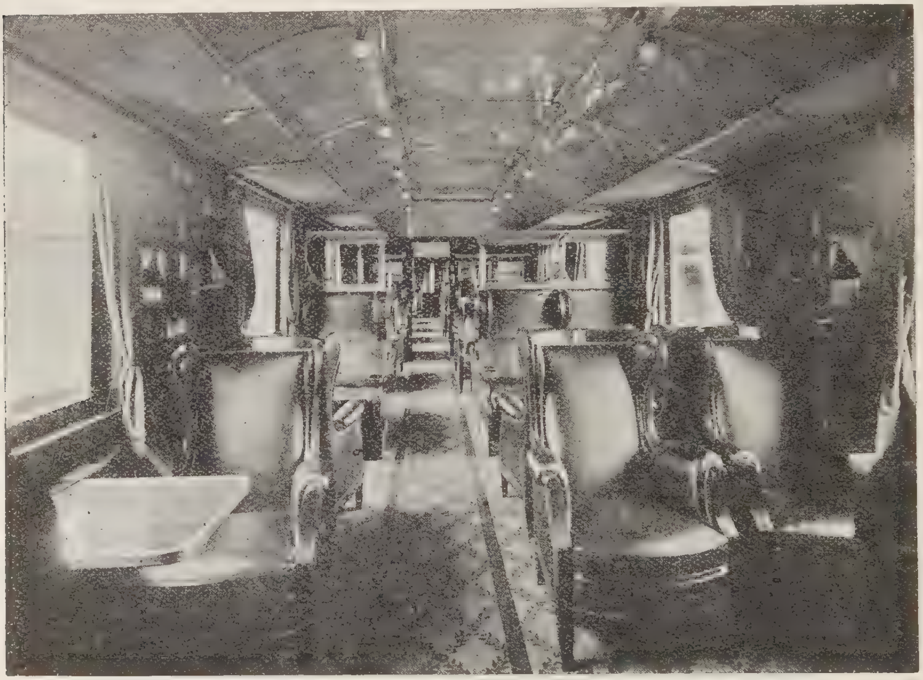

Fig. 347. — Interior of ordinary car, *Swedish State Railways.*

XLIX-7. — **Train speeds.** — The cartogram of train speeds (fig. 326) shows the main traffic currents, which do not always follow the main lines mentioned in the course of this article. Table 294 gives further details, and includes even long-distance services at moderate speeds.

Private Companies still operate a number of railways, some of them very long, several with expresses whose overall speed does not exceed 80 km. (50 miles) an hour. The longest non-stop run is 73 km. (45.4 miles).

Since the introduction of electric traction, there has been a noteworthy increase in train speeds.

LONG NON-STOP RUNS. — Although the

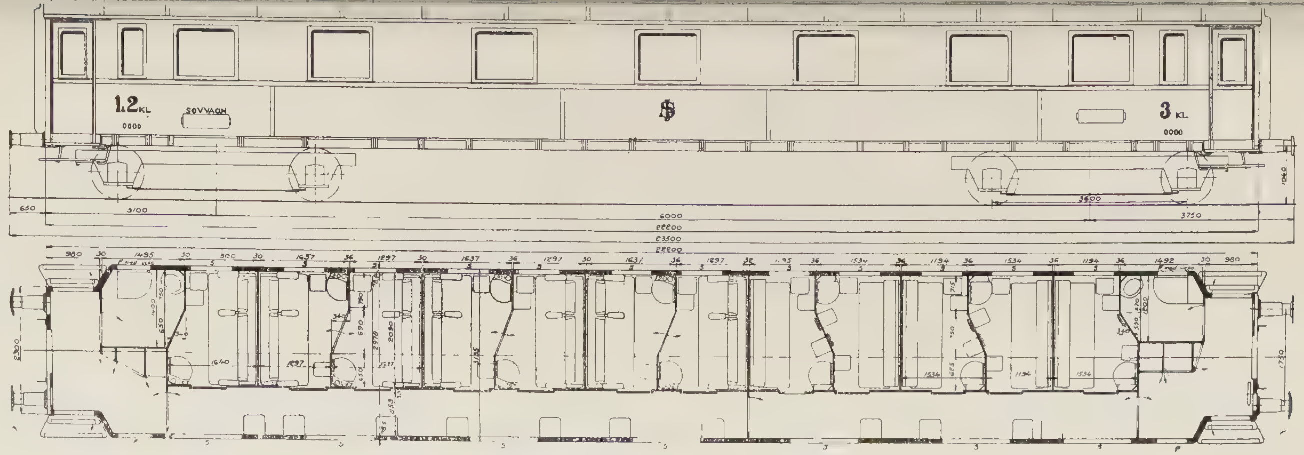

Fig. 348. — *Swedish State Railways'* sleeping car.

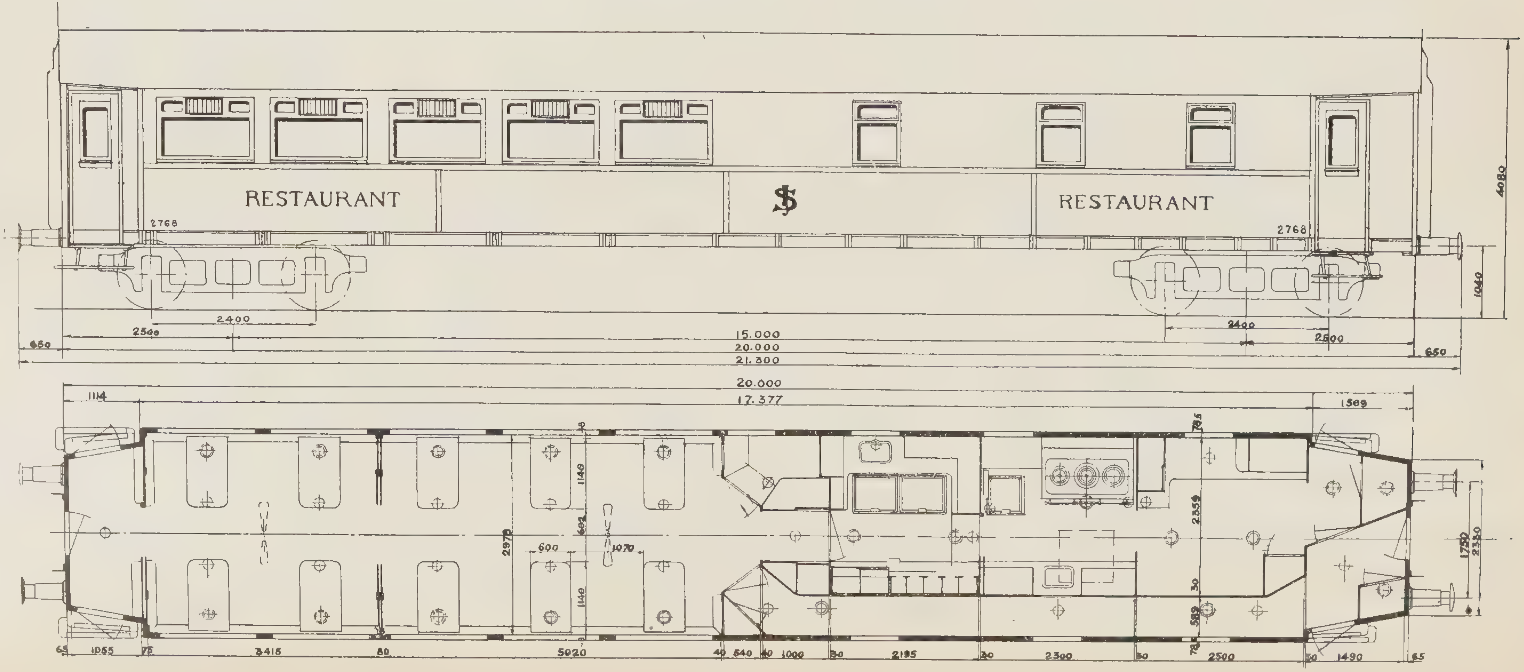

Fig. 349. — *Swedish State Railways'* restaurant car.

TABLE 294.

NOTEWORTHY SWEDISH TRAIN SPEEDS (fig. 326).

(Non-stop runs are shown in **heavy type**).

RUN.	Distance.		Time of departure.	Time spent.	Number of stops.	Speed.		—
	Km.	Miles.				Km./h.	Miles/h.	
State Railways.								
Lulea-Boden-Riksgränsen-Narvik . .	479	297.6	R 11.20 a. m.	8.56	...	50.4	31.3	Electric.
Lulea-Boden-Riksgränsen (Narvik) .	433	269.1	7.09 p. m.	14.29	33	20.9	13.0	Do.
Gällivare-Kiruna	100	62.1	**11.24** p. m.	**1.24**	...	**71.4**	**4.44**	Do.
Stockholm-Uppsala-Bräcke-Boden . .	1144	710.8	10.00 a. m.	22.26	43	58.9	36.6	
(Stockholm)-Bräcke-Storlien (Trondheim)	748	464.8	7.10 p. m.	14.25	17	60.2	37.4	
Änge-Östersund	102	63.4	**R 10.15** p. m.	**1.39**	...	**61.8**	**38.4**	
Stockh.-Uppsala-Krylbo-Änge (etc.) .	484	300.7	10.00 a. m.	8.27	9	59.3	36.8	
Stockholm-Uppsala	66	41.0	**4.45** a. m.	**0.50**	...	**79.2**	**49.2**	Electric.
Uppsala-Sala	62	38 5	**5.29** p. m.	**0.46**	...	**80.9**	**50.3**	Do.
Sala-Krylbo	33	20.5	**6.16** p. m.	**0.26**	...	**76.2**	**47.3**	Do.
Stockholm-Uppsala-Gävle-Härnosänd.	481	298.9	3.10 p .m.	8.18	18	57.7	35.9	
Uppsala-Alvkarleo	88	54.7	**5.45** a .m.	**1.30**	...	**58.7**	**36.5**	
Stockholm-Laxa-Charlottenberg-Oslo .	431	267.8	8.45 a. m.	6.44	8	64.1	39.8	
Laxa-Strömtorp	37	23.0	**2 52** a. m.	**0 31**	...	**71.9**	**44.7**	
Kristinehamn-Karlstad C. . . .	41	25.5	**R 12.35** a. m.	**0.34**	...	**72.4**	**45.0**	
Stockholm-Katrineholm-Göteborg . .	456	283.3	8.45 a. m.	6.05	7	74.9	46.5	Electric.
Södertälje-Katrineholm	98	60.9	**9.15** a. m.	**1.13**	...	**80.5**	**50.0**	Do.
Katrineholm-Hallsberg	66	41.0	**10.32** a. m.	**0.47**	...	**82.9**	**51.5**	Do.
Laxa-Skövde	84	52.2	**11.54** a. m.	**1.01**	...	**82.6**	**51.3**	Do.
Falköping-Göteborg	114	70.8	**R 2.20** p. m.	**1.27**	...	**78.6**	**48.8**	Do.
Herrljunga-Göteborg	80	49.7	**1.51** p. m.	**0.59**	...	**81.3**	**50.5**	Do.
Falköping-Herrljunga	34	21.1	**4.52** a. m.	**0.25**	...	**85.6**	**53.2**	Do.
Stockholm-Nyköping-Malmö	599	372.2	8.00 a. m.	8.05	11	74.0	46.0	Electric.
Stockholm-Nässjö	330	205.1	Do.	4.30	6	73.3	45.5	Do.
Stockholm-Södertälje S.	35	21.7	**5.00** a. m.	**0.30**	...	**70.0**	**43.5**	Do.
Södertälje-Nyköping	69	42.9	**8.30** a. m.	**0.52**	...	**79.5**	**49.4**	Do.
Stockholm - Katrineholm - Norrköping (Nässjö)	181	112.5	...	...	...	...	...	Do.
Katrineholm-Norrköping C. . . .	48	29.8	**1.00** a. m.	**0.37**	...	**77.8**	**48.3**	Do.
Stockholm direct Nyköping-Norrköping (Nässjö)	163	101.3	...	...	...	...	...	Do.
Stockholm-Katrineholm	133	82.6	**R 1.13** p. m.	**1.41**	...	**79.1**	**49.2**	Do.
Nässjö-Alvesta	87	54.1	**2.29** a. m.	**1.01**	...	**85.6**	**53.2**	Do.
Alvesta-Hässleholm	98	60.9	**1.40** p. m.	**1.11**	...	**82.8**	**51.4**	Do.
Hässleholm-Eslöv	50	31.0	**2.56** p. m.	**0.36**	...	**83.3**	**51 8**	Do.
Stockholm-Malmö-Trälleborg . . .	630	391.5	1.30 p. m.	9.01	16	70.0	43.5	Do.
Malmö-Trälleborg	31	19.3	**8.00** a. m.	**0.26**	...	**71.6**	**44.5**	Do.
Trälleborg-Sassnitz	107	66 5	**8.55** a. m.	**4.10**	...	**25.7**	**16.0**	Train ferry.
Krylbo-Mjölby	253	157 2	...	...	...	...	...	Electric.
Hallsberg-Motala C.	69	42.9	**3.33** p. m.	**0.53**	...	**78.1**	**48.5**	Do.
Motala C.-Mjölby	27	16.8	**4.27** p. m.	**0.21**	...	**77.1**	**47.9**	Do.

Table 294 (*continued*).

RUNS.	Distance.		Time of departure.	Time spent.	Number of stops.	Speed.		—
	Km.	Miles.				Km./h.	Miles/h.	
Stockholm-Falköping-Nässjö-Malmö	723	44.9	9.10 p. m.	10.21	16	67.6	42.0	Electric.
Falköping C.-Jönköping C. . . .	69	42.9	1 56 a. m.	0.52	...	79.9	49.6	Do.
Jönköping C.-Nässjö	43	26.7	2.50 a. m.	0.36	...	71.6	44.5	Do.
Trälleborg-Malmö-Göteborg-Kornsjö (Oslo)	518	32.2	8.56 p. m.	9.39	18	54.0	33.6	Electric as far as Halmstad.
Malmö-Kävlinge	24	14.9	10.00 p. m.	0.20	...	72.0	44.7	
Kävlinge-Billesholms	35	21.7	8.25 a. m.	0.29	...	72.4	45.0	
Varberg-Göteborg	77	47.8	R 3.40 p. m.	1.04	...	60.8	37 8	
Göteborg-Trollhättan	72	44.7	3.35 a. m.	1.00	...	72.0	44.7	
Oxnered-Mellerud	41	25.5	3.07 p. m.	0.33	...	74.6	46.4	
Mellerud-Ed	44	27.3	R 12.47 p. m.	0.42	...	62.9	39.1	*Company.*
Companies.								
Stockholm-Köping	146	90.7	4.13 p. m.	2.24	5+1 cond.	60.9	37.8	*Stockholm-Västeras Co.*
Stockholm-Enköping	73	45.4	Do.	1.02	...	70.6	43.9	*Do.*
Stockholm-Vansbro	298	185.2	2.38 p. m.	4.33	13+6 cond.	65.5	40.7	*Do.*
Stockholm-Rimbo-Gimo	115	71.5	1.50 p. m.	2.10	5	53.1	33.0	
Dj. Ösby-Rimbo	49	30.4	2.00 p. m.	0.52	...	50.7	31.5	
Stockholm C.-Nynäshamn	64	39.8	9.40 p. m.	1.15	5+1 cond.	51.2	31.8	*Stockholm-Nynäs-Järnväg.*
Älvrjö-Ösmo	43	26.7	9.55 p. m.	0.40	...	64.5	40.1	*Visby packet-boat train.*
Rättvik-Krylbo	128	79.5	1.25 p. m.	2.48	17	...	...	*Södra-Dalarnes-Järnväg.*
Insjon-Borlänge	35	21 7	9.15 p. m.	0.40	...	52.5	32.6	*Do.*
Hedenora-Avesta	19	11.8	3.49 p. m.	0.19	....	60.0	37.3	*Do.*
Falun-Kil-Göteborg	478	297.0	9.00 a. m.	8.25	17	56.8	35.3	Transverse line.
Mellerud-Öxnered	41	25.5	1.33 p. m.	0.31	...	80.0	49.7	*Bergslagernas Järnväg-Göteborg.*
Trollhättan-Göteborg	72	44.7	12.29 a. m.	0.59	...	73 2	45.5	*Do.*
Göteborg-Karlskrona	353	21.9	2.50 p. m.	6.55	...	51.0	31.7	3 Companies.
Göteborg-Limmared (Karlskrona) .	221	137.3	Do.	4.10	12+2 cond.	53.0	32.9	*Göteborg-Alvesta Järnväg.*
Göteborg-Boräs C.	72	44.7	9 00 a. m.	1.10	...	61.7	38.3	*Do.*
Boräs C.-Limmared	40	24.8	4.10 p. m.	0.40	...	60.0	37.3	
Alvesta-Växjo	18	11.2	7.25 p. m.	0.18	...	60.0	37.3	*Alvesta-Växjö Järnväg.*
Växjo-Karlskrona	114	70.8	7.49 p. m.	1.56	3	58.3	36.2	*Karlskrona-Växjö Järnväg.*
Växjo-Hovmanstorp	25	15.5	Do.	0.25	...	60.0	37.3	*Do.*
Emmaboda-Karlskrona	57	35.4	8.50 p. m.	0.55	...	62.2	38.7	
Hässleholm-Hälsingborg C.	77	47.8	3.05 p. m.	1.18	4	59.2	36.8	
Astorp C.-Hälsingborg C.	24	14.9	3.59 p. m.	0.24	...	60.0	37.3	
Malmö-Soedala-Ystad	63	39.1	11.30 p. m.	1.12	5+1 cond.	52.5	32.6	*Malmö-Ystad Järnväg.*
(Göteborg) Mellerud-Kornsjö-Mellerud-Edj	44	27.3	R 12.47 p. m.	0.42	...	62.9	39.1	*Dalslands-Järnväg.*

timetables quote a non-stop Hässleholm-Stockholm run since 1912, there have always been a certain number or service stops in the course of the 552 km. (343 miles), to change engines at Alvesta and Katrineholm, and elsewhere to take water. The longest really non-stop run takes place between Katrineholm and Stockholm (134 km. = 83.3 miles) at an overall speed of 55.8 km. (34.7 miles) an hour.

TABLE 295.

SWEDISH NON-STOP RUNS.

RUN.	Distance.		Time of departure.	Time spent.	Speed.		—
	Km.	Miles.			Km./h.	Miles/h.	
FASTEST RUNS.							
Steam traction.							
(Oslo) Mellerud-Öxnered	41	25.5	*1.33* p. m.	*0.31*	*80.0*	*49.7*	*Company* (Summer).
(Stockholm) Kristinehamn-Karlstad C.	41	25.5	R 12.35 a. m.	0.34	72.4	45.0	
Trollhättan-Göteborg	72	44.7	R 3.35 a. m.	1.00	72.0	44.7	
Electric traction.							
(Stockholm) Falköping-Herrljunga	34	21.1	4.52 a. m.	0.25	85.6	53.2	
(Do.) Nässjö-Alvesta	87	54.1	2.29 a. m.	1.01	85.6	53.2	
(Do.) Hässleholm-Eslöv	50	31.1	2.56 p. m.	0.36	83.3	51.8	
(Do.) Katrineholm-Hallsberg	66	41.0	10.32 a. m.	0.47	82.9	51.5	
(Do.) Alvesta-Hässleholm	98	60.9	1.40 p. m.	1.11	82.8	51.4	
(Do.) Laxa-Skövde	84	52.2	11.54 a. m.	1.01	82.6	51.3	
(Do.) Herrljunga-Göteborg	80	49.7	1.51 p. m.	0.59	81.3	50.5	
(Do.) Södertälje-Katrineholm	98	60.9	9.15 a. m.	1.13	80.5	50.0	
(Do.) Falköping C.-Jönköping C.	69	42.9	1.56 a. m.	0.52	79.9	49.6	
LONGEST NON-STOP RUNS.							
Steam traction.							
(Stockholm Änge-Östersund	102	63.4	R 10 15 p. m.	1.39	61.8	38.4	
(Do.) Uppsala-Alvkarleo	88	54.7	5.45 a. m.	1 30	58.7	36.5	
Electric traction.							
Stockholm-Katrineholm	133	82.6	R 1.13 p. m.	1.41	79.1	49.2	
(Stockholm) Falköping-Göteborg	114	70 8	R 2.20 p. m.	1.27	78.6	48.8	
(Lulea) Gällivare-Kiruna	100	62.1	11.24 p. m.	1.24	71.4	44.4	
(Stockholm) Södertälje-Katrineholm	98	60.9	9.15 a. m.	1.13	80.5	50.0	
(Do.) Alvesta-Hässleholm	98	60.9	1.40 p. m.	1.11	82.8	51.4	
(Do.) Nässjö-Alvesta	87	54.1	2.29 a. m.	1.01	85.6	53.2	
(Do.) Laxa-Skövde	84	52.2	11.64 a. m.	1.01	82.6	51.3	
Train ferry service.							
Trälleborg-Sassnitz	107	66.5	8.55 a. m.	4.10	25.7	16.0	

Such occurrences, of so called non-stop runs where service stops are nevertheless included are fairly frequent. Thus on the *Est Railway* (France), the 443-km. (275.3 miles) Belfort and Paris non-stop run nevertheless included service stops at Chaumont and Troyes;

On the French *Nord*, between Calais

and Paris, there was a service stop to take water at Abbeville;

In Belgium on the Ostend-Verviers non-stop run, a service stop took place at either Malines or Louvain;

In Italy, on many runs still booked as non-stop, there are similar stops.

Another frequent case of non shown stops is due to reversals outside certain stations, which the through trains avoid. Until recently, this was the case in Switzerland, between Buchs and Sargans (« Arlberg Express »), in Jugoslavia (« Simplon Express »), outside Amiens, for Paris-Lille trains, etc.

Goods train speeds need not be commented upon here; table 296 shows the more noteworthy speeds of such trains.

TABLE 296.

SPEED OF MAIN-LINE GOODS TRAINS.

RUN.	Distance.		Time of departure.	Time spent.	Speed.		Train number.
	Km.	Miles.			Km./h.	Miles/h.	
Malmö-Boden . . .	1 594	991.1	8.20 p. m.	58.30	27.2	16.9	4350
Stockholm (Tomteboda)-Änge	481	298.9	12.43 a. m.	20.05	24.0	14.9	4202
Stockholm-Malmö . .	600	372.8	11.40 p. m.	26.10	23	14.3	4001
Do. -Göteborg .	455	282.7	7.36 p. m.	11.00	41.4	25.7	4041
Göteborg-Malmö . .	300	186.4	7.33 p. m.	12.00	25	15.5	5151

The longest non-stop runs are the following :

Mjölby-Hallsberg.	96 km.	(59.6 miles).
Uppsala-Krylbo	95 km.	(59.0 miles).
Mjölby-Nässjö.	89 km.	(55.3 miles).
Södertälje-Södra-Hallsberg . .	163 km.	(101.3 miles).
Göteborg-Varberg	77 km.	(47.8 miles).

XLIX-8. — **Conclusion.** — Over half the *State Railways*, i. e. three quarters of the whole Swedish railway system, no trains reach an overall speed of 60 km. (37.4 miles) an hour.

Mileages covered at various average speeds, together with the corresponding percentage of the entire system, are given hereunder :

Over 80 km. (50 miles) an hour	609 km.	(378.4 miles), i. e.	8.1	%.
70 to 79.9 km. (44 to 49.9 miles) an hour .	1 317 km.	(818.4 miles), i. e.	17.6	%.
60 to 69.9 km. (38 to 43.9 miles) an hour.	1 916 km.	(1 190.5 miles), i. e.	25.3	%.
Under 60 km. (38 miles) an hour.	3 686 km.	(2 290.4 miles), i. e.	49	%.
The whole system.	7 528 km.	(4 677.7 miles), i. e.	100	%.

XLIX-9. — **Appendix.** — **The boat services.** — These services have grown considerably, not only on the Baltic, but also on many of the navigable rivers, canals, and large lakes which abound in the country (1). The speed is usually moderate.

(To be continued).

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(1) The largest lake, Lake Vänern, 44 m. (144′) above sea level, has a maximum length of 182 km. (113 miles) and is 84 km. (52 miles) broad. Its area, 2 150 square miles, is considerably reduced owing to two long peninsulas, Nasö and Kollunds, which actually divide it up longitudinally into two lakes separated by a wide strait. Its maximum depth is 88 m. (289′).

Lake Vattern (88 m. = 289 above sea level), 128 km. (79.5 miles) long, with a maximum width of 30 km. (18.6 miles), has an area of 733 square miles. In the southern part, the depth varies between 79 and 91 m. (259′ and 299′), in the North, between 20 and 30 m. (66′ to 99′).

[625.4 (.47)]

Moscow's Underground Railway,

by P. KANDAOUROFF, Engineer, Paris.

General.

High-speed urban or metropolitan railways date from 1863 when the first such railway was opened in London. It was the only one in the world for many years, as those in America, in New York itself, were elevated railways (¹). This system is now only used alongside roads with much room on each side of the viaduct, as in Paris, but when steam traction had to be used, it was almost inevitable, as steam traction was very unsatisfactory for underground working.

Metropolitain railways developed considerably in Europe with the improvement of electric traction, and especially in Paris where the Metropolitan carries many more people than any other means of transport in common (²).

A metropolitan railway, of course, is only really required in a city of some size, especially if one of the old capital cities which have slowly grown throughout the ages. Such a railway only becomes important and only gives the service expected from so costly an undertaking when there is such a network of lines that the passengers can be set down within walking distance of their final destination.

II. — Historical review.

From this point of view, cities such as Paris and Moscow, built on a definitely concentric plan, lend themselves particularly well to the construction of a metropolitan railway system.

Moscow, like Paris, has two circular boulevards round the city, built on the site of the old fortifications, the first of which was demolished in the middle of the 18th century, and the second after the fire of 1812.

The question of building a metropolitan railway in Moscow was raised before the war, as the population had grown to 1 984 000 in 1916.

This is approximately the critical population figure for the cities of the old world at which the need for better means of transport begins to be felt really seriously, as is shown by the diagram, figure 1.

The schemes were not proceeded with twenty years ago because of the war and the revolution. Only in 1931 did the Soviet Government undertake a more careful investigation into the problem and subsequently take its construction in hand.

---

(1) The first of these railways was opened in 1875.

(2) This is not so, however, in the other European capitals. The following table gives the number of passengers carried during 1926 by the three principal forms of locomotion in London, Berlin, and Paris (in millions) :

	London	*Berlin*	*Paris*
Tramways	970	813	343
Motorbuses.	1716	113	316
Underground	878	163	615

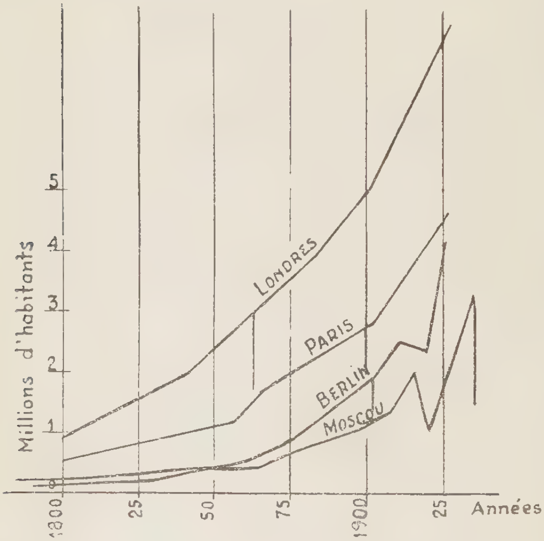
(*Archiv für Eisenbahnwesen*, 1932, p. 892).

III. — Layout adopted.

In 1931 a detailed study of a series of lines shown in the plan (fig. 2) (*) was made.

The total length of the ten lines radiating from the centre of the city is 80 km. (50 miles).

From an operating point of view there will be fewer lines because lines 1 and 2, 3 and 4, as well as 5 and 6, either in use or under construction, will be run over from end to end by the same trains [3].



▍ *Opening of first underground :* London, 1863; Paris, 1900; Berlin, 1902; Moscow, 1935. — *The last ordinates correspond to the number of inhabitants including those in the suburbs.*

Fig. 1. — Diagram showing the growth of the population of London, Paris, Berlin and Moscow.

The investigation took about a year and the construction of the central section of lines NN 1, 2, and 3 were started in 1932. These lines were opened to traffic on the 15th May 1935.

Line N 1 is obviously the most important as regards city traffic because, besides giving access to the outlying districts of the city, it connects three Moscow stations, the Northern, Kazan and Leningrad, lying side by side in the « Communist Youth » Square, with the commercial part of the city, and the first two of these stations handle a good deal of the suburban traffic.

The total length of lines now in operation is 11.413 km. (7.1 miles. Work on three other lines was begun in 1935. One of these, the N 4 also runs eastwards like N 1 and is about 8.5 km. (5.3 miles) long. This line connects with the principal station for the Kursk and Nijny-Novgorod (now Gorki) main lines. The second line, the N 5 to the North-West, for the time being ends at the « White Russia and Baltic Sea » station (Warsaw station). The third line, the N 6, running southwards, will end at the intersection with the outer boulevards near the Saratow station. The aggregate length of these lines will be 8 km. (5 miles).

The N 2 line is now being extended 1 km. (0.62 mile) towards the Kiev station.

The other projected lines have not yet been started and will therefore not be mentioned here. The drawings for these lines are not yet completed and the schemes may be considerably modified.

The minimum radius of curves laid down in principle is 200 m. (10 chains), although at one point in the centre of the city a curve of 120 m. (6 chains)

(*) According to the map of Moscow in the « Stielers Handatlas » by Justus Perthes, Gotha.

[3] The circular lines have not yet been taken in hand. The completion of the lines on the map will take a long time and no one knows when work on the circular lines will be started.

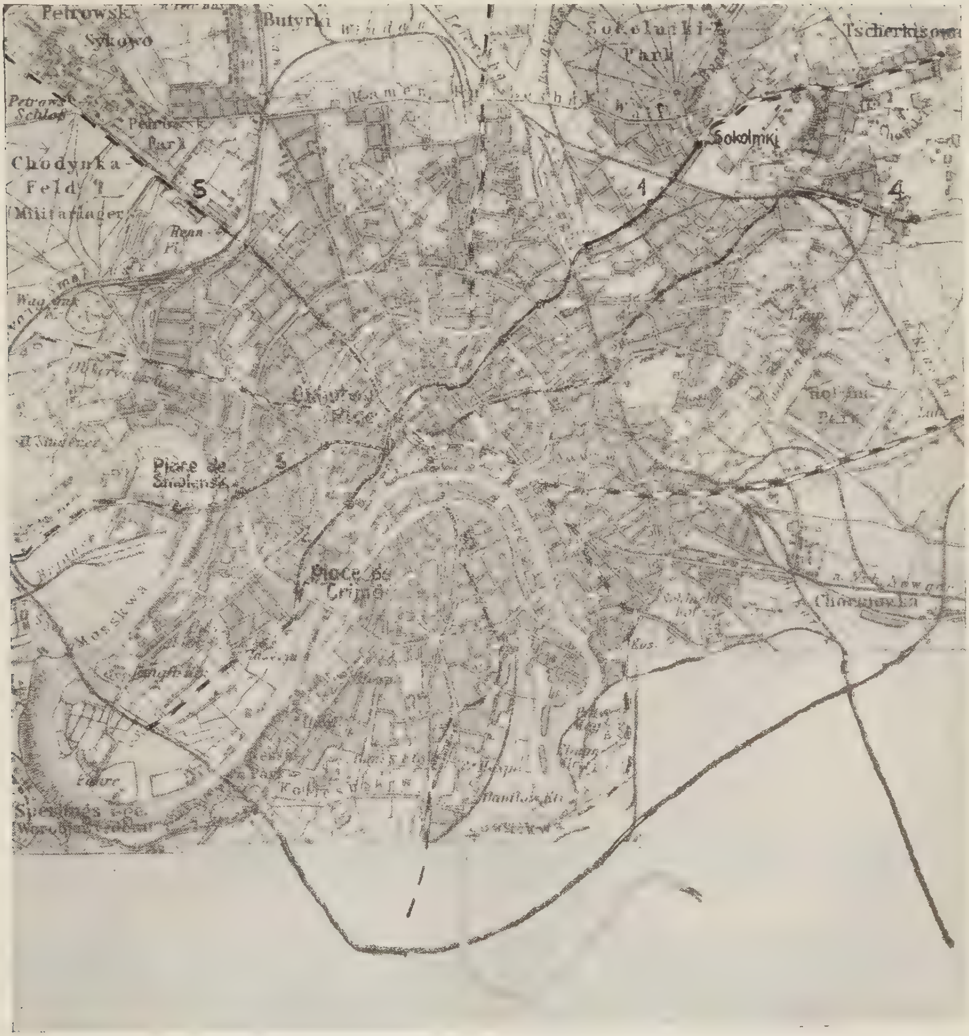


Fig. 2. — Plan of Moscow. — Scale, 1:100 000

radius has had to be used. The maximum gradient is 1 in 30 (4).

The gradient section of the line more or less follows the configuration of the

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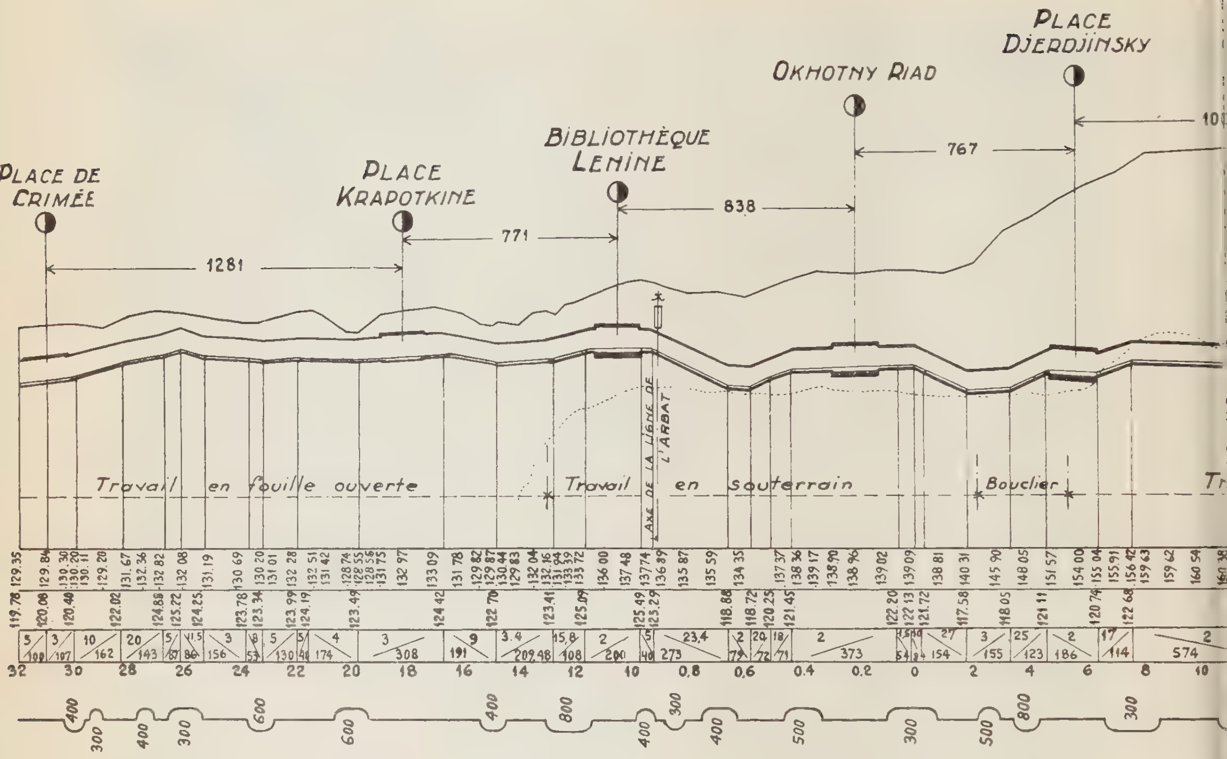
(4) The gradient of 33 mm./m. (1 in 30) is almost standard in underground construction, the maximum in Paris and Berlin being 40 mm./m. (1 in 25). As regards minimum radii, they are much smaller in Paris where there are curves of 50 m. (2 1/2 chains) radius on the running lines and even one of 36.75 m. (1.83 chains = 121 feet) radius on the western approach of the Bastille station on line N1.



3. — Gradient section of lines NN 1 and 2. —

Explanation

Travail en fouille ouverte = work carried out in open cutting. — Travail en souterrain = tunnel work. — Bouclier = shield. — Limite supérieure du calcaire dur = upper limit of hard limestone. — Fouille = excavation. Axe de la ligne de jonction entre les gares de Kursk et de Leningrad = centre line of junction between the

ground except in the section between the « Communist Youth Square » (5) and the « Okhotny Riad » stations (figs. 3 and 4). The line in this section passes below one of the highest parts of Moscow, the level near the Kirowskaia being 160 m. (525′) above datum (6). This station is also the deepest, the platforms being 35.20 m. (115′) below street level (7). Between the « Communist Youth » and « Red Gate » stations the line drops 12.80 m. (42′) to avoid the unstable subsoil above it, as shown in the gradient section. This precaution was the more necessary as this section of line N 1 lies under the narrow and winding Kirowskaia street (8), one of the

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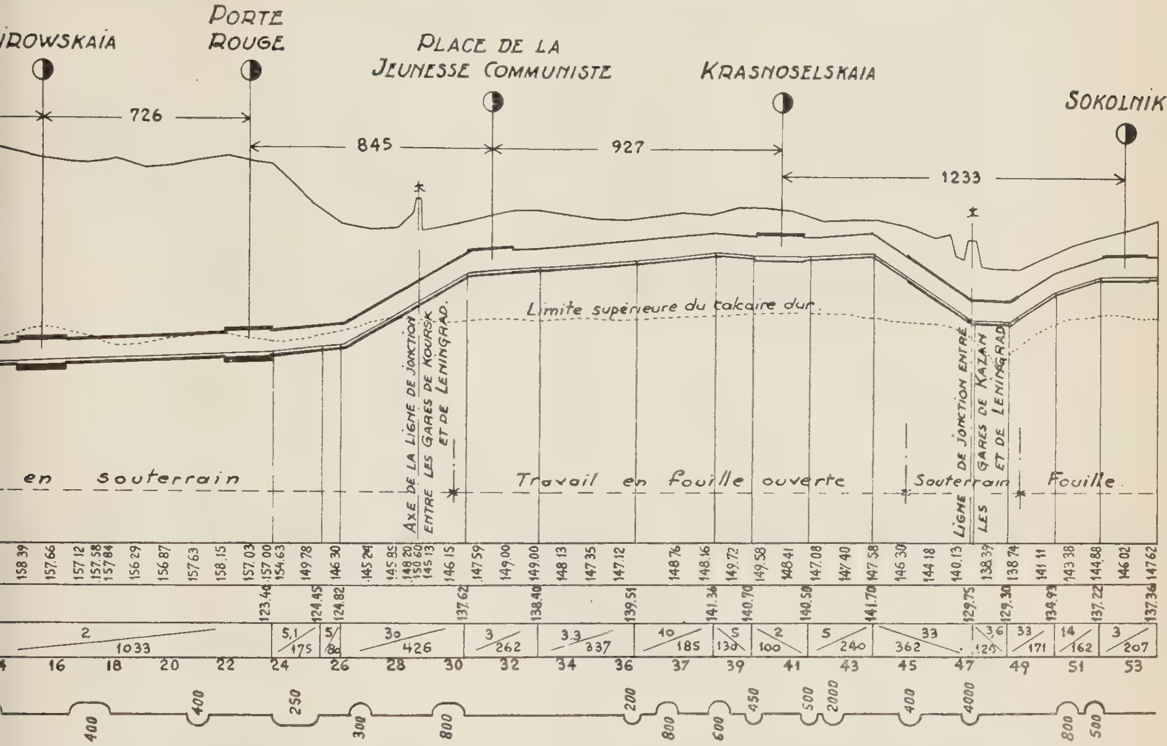
(5) The Russian names being difficult to pronounce, are translated into English whenever possible.

(6) In front of the Kremlin, the Moskowa is 116 m. (381′) above datum.

(7) The platform of the Abbesses and Buttes-Chaumont stations in Paris is 29.90 m. (99′) and 29.60 m. (98′) below the roadway.

(8) Formerly the Miasnitzkana street.


IROWSKAIA
PORTE ROUGE
PLACE DE LA JEUNESSE COMMUNISTE
KRASNOSELSKAIA
SOKOLNIKI
726
845
927
1233
Limite supérieure du calcaire dur
Axe de la ligne de jonction entre les gares de Koursk et de Leningrad
Ligne de jonction entre les gares de Kazan et de Leningrad
en souterrain
Travail en fouille ouverte
Souterrain
Fouille
16
18
20
22
24
26
28
30
32
34
36
37
39
41
43
45
47
49
51
53

Length, 1 in 26 667. — *Height*, 1 in 1 333.

terms :

Kursk and Leningrad stations. — Ligne de jonction entre les gares de Kazan et de Leningrad = junction line between the « Kazan » and « Leningrad » stations.

main streets of Moscow, with large buildings on each side.

The rest of the tunnel is fairly shallow.

As there is no private property under the Soviet regime, the line was built, where this was found advantageous, either under whole blocks of houses, instead of following the general direction of a street in order to avoid too sharp curves or under blocks of flats or courtyards along a road. The first case is found between the Red Gate and Kirowskaia stations (fig. 5), and the second almost the whole length of line N 3 along the Arbat and Komintern streets (fig. 6).

By building the underground in this way, the traffic in the most crowded streets of the capital was not interfered with in any way. As the bottom of the tunnel is only 8 to 9 m. (26′ to 29 1/2″) feet) below street level, had the tunnel not been located as stated, the roads would have has to be closed.

IV. — Layout and equipment of the stations.

There are 13 stations on the 11.413 km.

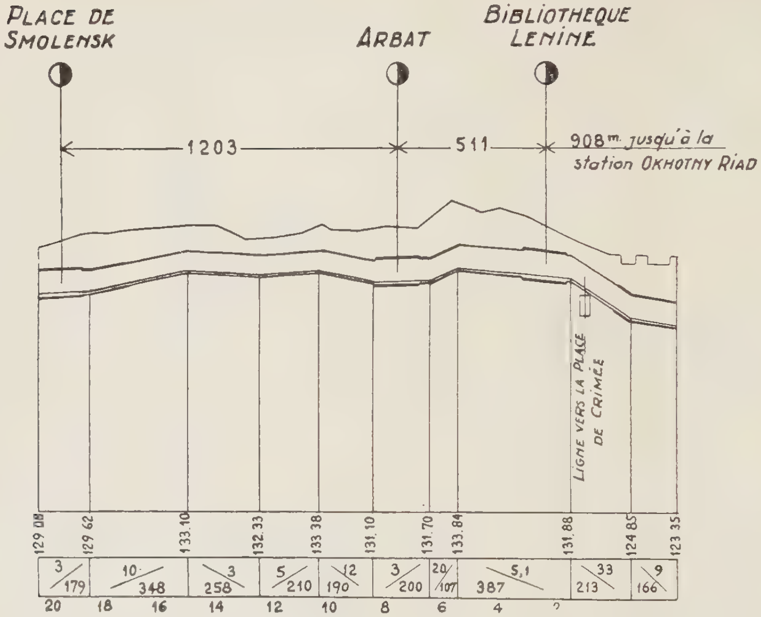


Fig. 4. — Gradient section of line N 3.

Note : 908 m. jusqu'à..... = 993 yds. to the « Okhotny Riad » station.

(7.1 miles) of line in service, 511 to 1 281 m. (559 to 1 401 yards) apart, the average being 918 m. (1 004 yards), a much greater distance than that of the other metropolitan railways (⁹).

With the exception of the « Lenin Library » station, on line N 3, island platforms are arranged between the station tracks. One of the advantages of this layout is that the common part of the platform can be used freely during rush hours when, with the exception of the stations in the centre of the city, most of the passengers travel in the same direction.

The stations just below the ground have the roof supported by one or two rows of columns (fig. 7). The deeper stations are either in a single tube (« Lenin Library »), two tubes (« Dzierdjinsky Square » and « Kirowskaia » stations), or three tubes (« Okhotny Riad » and « Red Gate » stations).

The minimum width of the platforms is 4 m. (12′ 1 1/2″) from the edge to the side of the columns facing the edge. The platform width in the « Lenin Library » Station, in which there are no columns, is 8 m. (26′ 3″) edge to edge.

The layout with a single line of columns or two tunnels is justified by the saving obtained by reducing the roof

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(9) The average distance between stations is 491 m. (537 yards) in Paris, 779 m. (852 yards) in Berlin, and 710 m. (776 yards) in New York, excluding the passages under the Hudson and East rivers. The short distance between its stations is one of the great advantages the Paris metropolitan has over the others.

span or the diameter of the tube (10) though the advantage of two rows of 405 mm. × 405 mm. (16″ × 16″) section columns only 2.69 m. (8′ 9 7/8″) apart, as in the « Communist Youth » station, for example, is not clear. It would have been cheaper to increase the span by 1.15 m. (3′ 9 3/8″) if it were really necessary to have the same available platform width, i. e. 10-0.40 = 9.60 m. (31′ 6″). The additional platform width could have been better used if this has been done as, for example, by providing benches as in Paris, there being no seats at all in the Moscow underground.

This design appears still less happy in the case of deep stations such as the « Okhotny Riad » or the « Red Gate ». In the former (figs. 9, 10 and 11) the central tube increases the minimum width of 22 m. (72′ 2 1/8″) by 10.35 m. (33′ 11 1/2″) so that the volume to be excavated was increased by 47 %. When the platforms are full in the rush hours, which rarely happens, even in Paris, the public could have been made to wait in waiting rooms at the surface level.

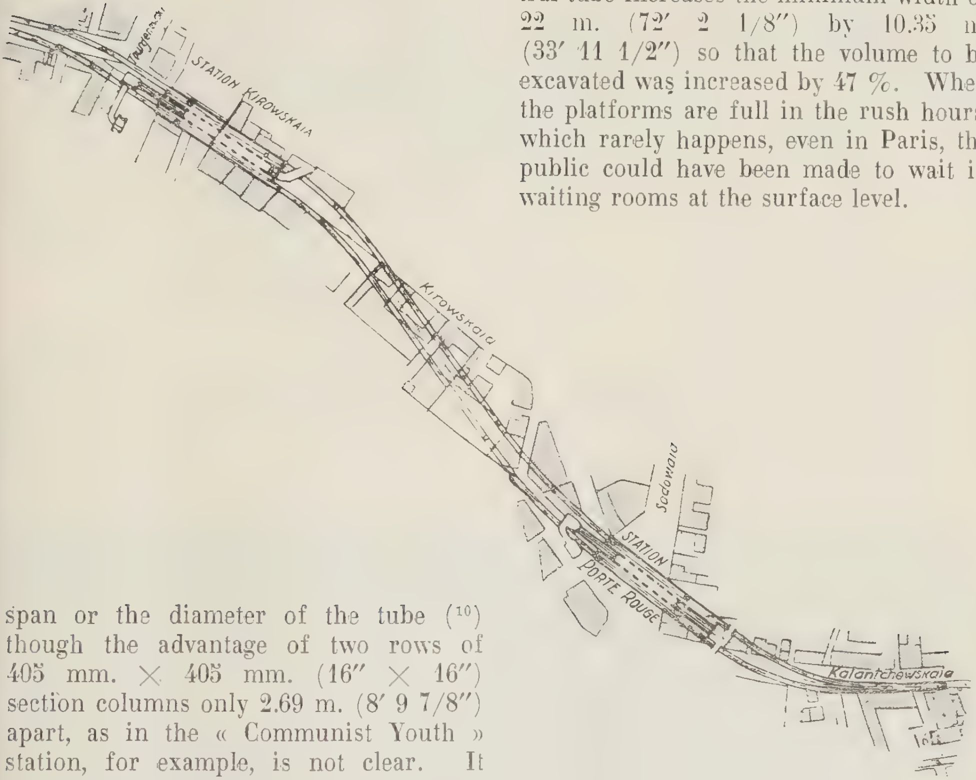

Fig. 5. — Plan of line N 1 between the « Red Gate » and « Kirowskaia » stations.

In all stations the platforms are accessible from both ends. Additional steps are installed a short distance from the platform ends in the stations with heavy traffic.

The deep stations — « Red Gate », « Kirowskaia », « Dzierdjinsky Square » and « Okhotny Riad » — have three mecha-

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(10) This arrangement is also adopted in Paris in the case of the very deep stations such as the « Buttes-Chaumont » and « Télégraphe ».

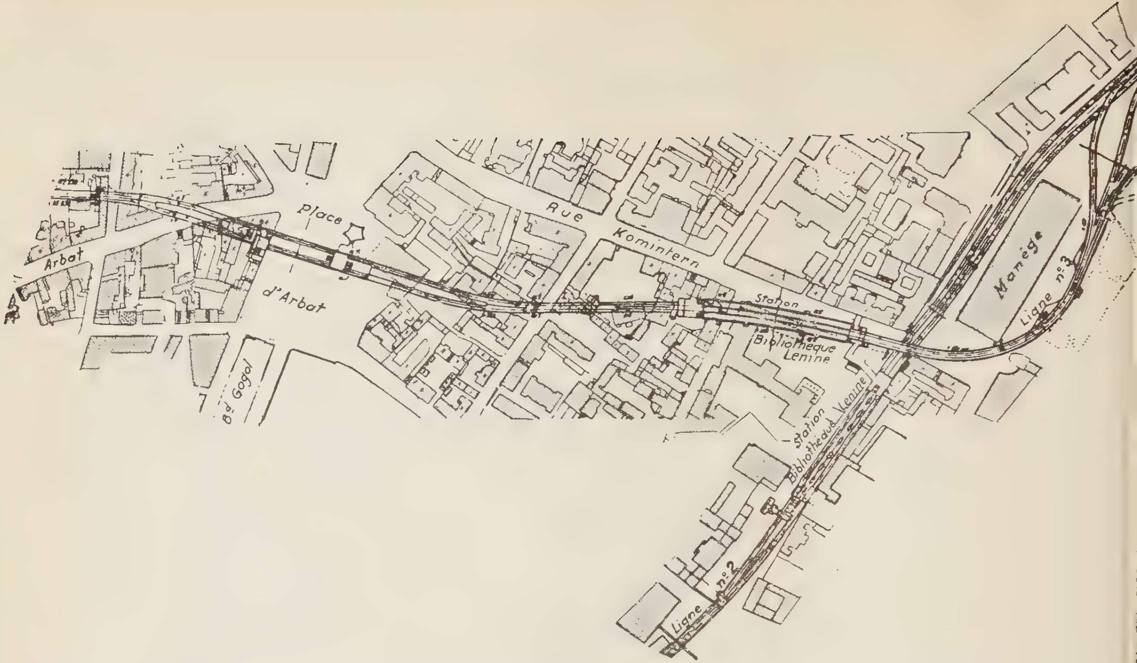

Fig. 6. — Plan of lines NN 2 and 3 near « Komintern » and « Arbat » Streets.

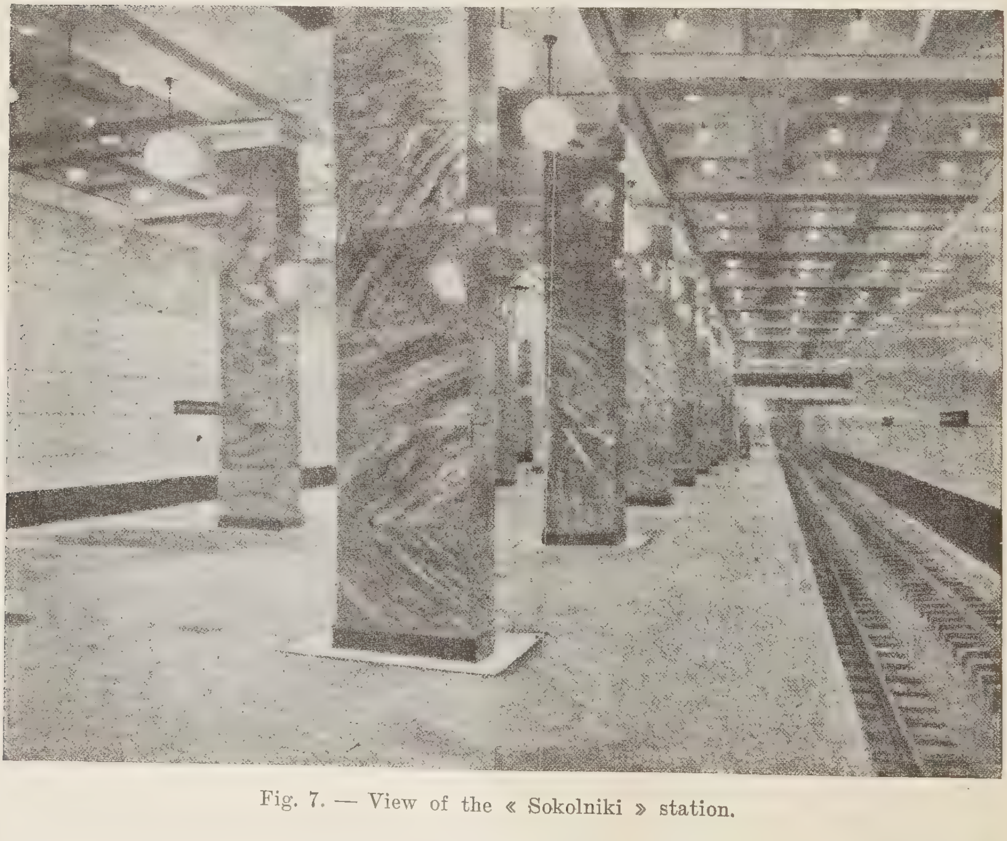

Fig. 7. — View of the « Sokolniki » station.

nical escalators at each end. The slope of these escalators is 30° and their speed 0.68 m. (2.23 feet) per second in the « Okhotny Riad » and « Dzierdjinsky » stations, and 0.50 m. (1.64 feet) per second in the « Kirowskaia » and « Red Gate » stations. The capacity of each escalator is 13 200 and 9 000 passengers per hour. Normally two escalators work upwards and one downwards. Owing to the cold climate of Moscow, open-access stairways to the stations, as in most other West-European and American cities, are out of the question. Access to the Moscow tube is by special buildings erected in the streets or squares as, for example, on the « Arbat » Square (fig. 12) and by subways just below street level (fig. 9). These buildings are always built on the footpaths and never in the middle of the road nor on special refuges, so that passengers need never cross the road to get to them. Some of these entrances, as for example, at the « Okhotny Riad » station, have been located into existing buildings.

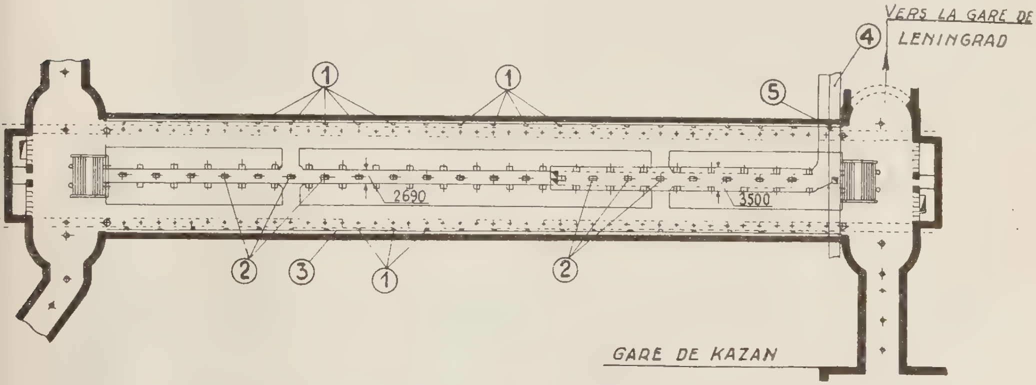

Fig. 8. — « Communist Youth » station. — Plan.

Legend:

1) 21 air-passage openings, 500 × 500 mm (1'7 11/16" × 1'7 11/16), in each side wall.
2) 8 air-passage openings, 1200 × 800 mm. (3' 11 1/4" × 2'7 1/2"), in the roof.
3) Air duct running along the wall, of 300 mm. × 1 700 mm. (11 13/16" × 5'7") section.
4) Air duct to the ventilating shaft, 1 800 mm. × 1 000 mm. (5'11" × 3'3 3/8") section.
5) Ventilating duct of 2 250 mm. × 1 000 mm. (7'4 19/32" × 3'3 3/8") section.

At the present time, the « Lenin Library » station is the only transfer station. The junction between lines NN 2 and 3 lies between this station and « Okhotny Riad » station, the lines crossing on the level. This is a only a temporary solution; the junction will be done away with, as when line N 4 is finished it will connect with N 3. As the NN 2 and 3 already cross one another at different levels (fig. 6) there will be no difficulty in carrying out this work.

The foundations of the « Smolensk Square », « Crimea » and « Arbat » stations have been designed to take into account the construction of further un-

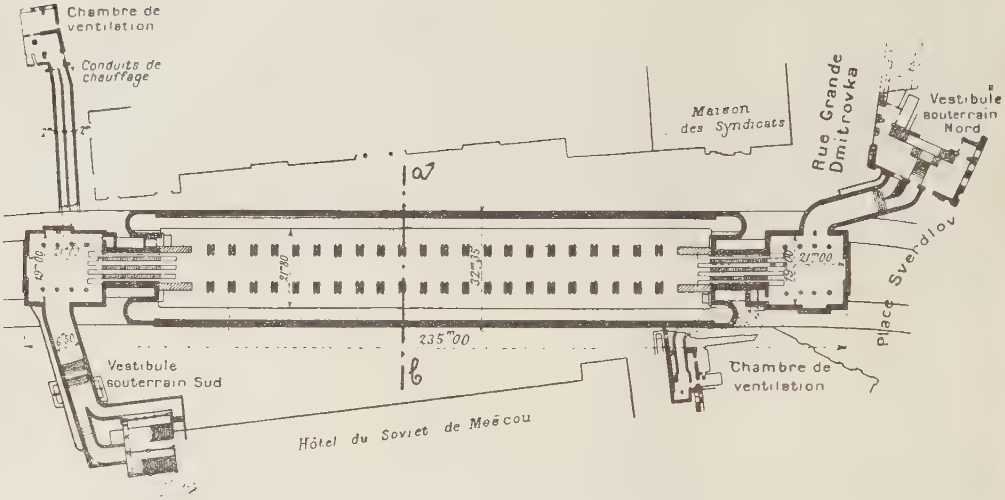

Fig. 9. — Plan of « Okhotny Riad » station.

Note : Chambre de ventilation = ventilation chamber. — Conduits de chauffage = heating ducts. — Vestibule souterrain Sud (Nord) = southern (northern) underground passage-way.

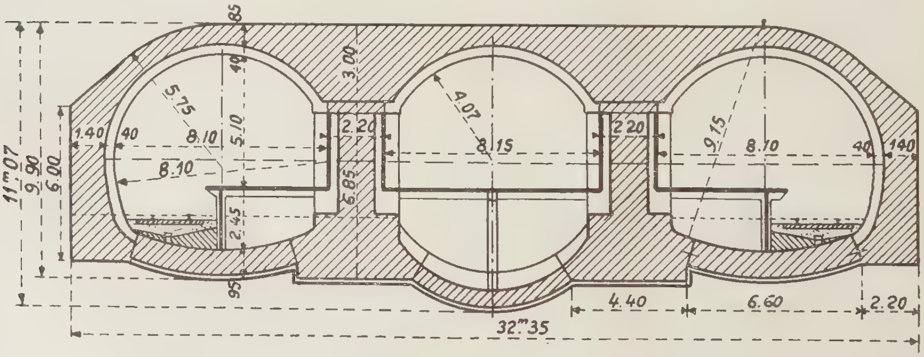

Fig. 10. — Cross section along *ab* of « Okhotny Riad » station.

dergound lines (11). Nothing appears to have been done at the other stations, not even at the « Okhotny Riad » station, which will be the central underground station of Moscow, so far as can be gathered from the official descriptions which generally give considerable details about even secondary matters.

A particular feature of the Moscow Underground stations is their architectural ornamentation and the absence of banality, both in the general conception

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(11) According to the article by *J. Vichniak* in the *Génie Civil*, second half-year 1935, p. 213. Figures 9, 10 and 11 are taken from this article.

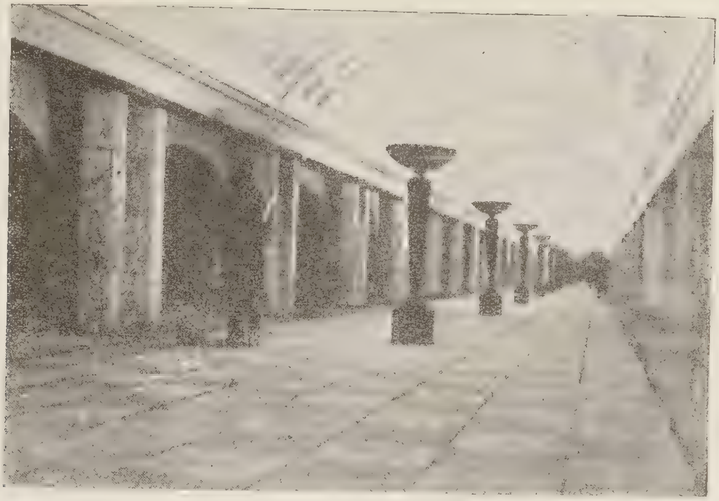

Fig. 11. — View of central passage-way in « Okhotny Riad » station.

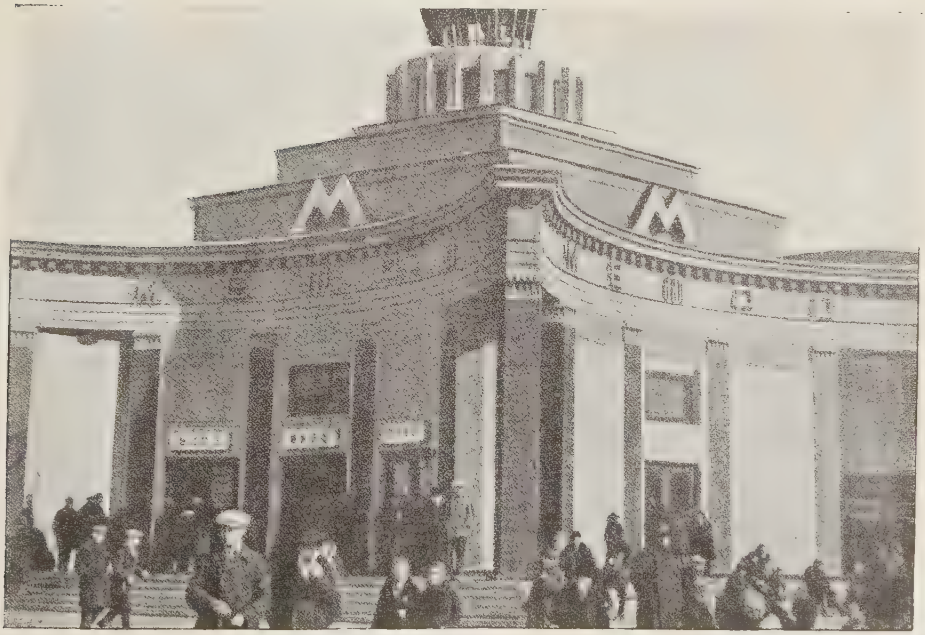

Fig. 12. — Entrance building at « Arbat » station.

and in the details of the exterior work, circulating areas, passages and platforms. The interior walls are usually lined in marble of a distinctive colour for each station. It may be questioned if such luxury and elaborate decoration is justified in the present financial position of the Soviet Republic. The cost, however, was only 28 million roubles or 106 million francs (¹²), which represents 4.5 % of the total cost, part of which would have had to have been expended in any case.

V. — Tunnels between stations.

Three designs have been followed :

1. Rectangular section with two tracks (fig. 13) used in shallow tunnels excavated in open cutting.

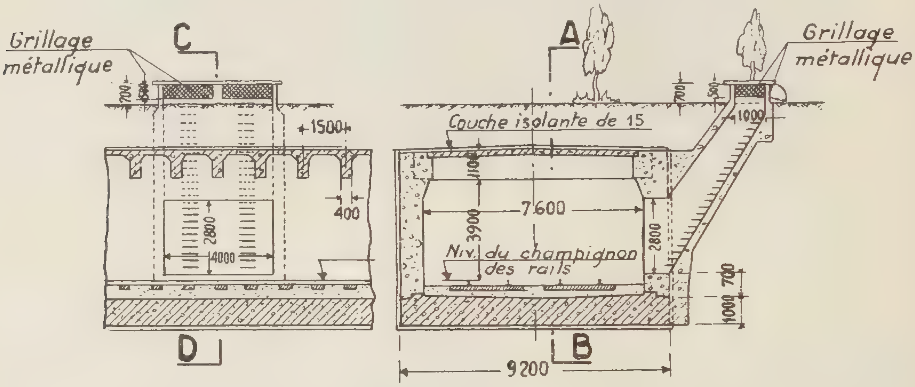

Fig. 13. — Double-track tunnel of rectangular section.

Note : Grillage métallique = metal lattice work. — Couche isolante de 15 = insulating layer 15 mm. (5/8") thick. — Niveau... rails = Level of rail top.

The invert and roof are in reinforced concrete with ribs dimensioned and spaced as shown in the drawing. The side walls are in concrete except in bad ground where reinforced concrete is used, so that on some lengths the lining forms a rigid frame which can easily stand the outside pressure.

The rectangular section has been used on some 7 km. (4.35 miles) of the tunnel.

Wherever there was any fear of water, special care was taken to prevent it getting into the tunnel, by using several layers of roofing felt or thin sheets of asphalt on canvas, several square metres in area. This material is mass-produced and supplied in rolls, which avoids the troublesome work involved in sticking on several layers of roofing on the walls.

2. Single heading for the two tracks driven in the usual way. These tunnels are 8.20 m. (26′ 10 13/16″) wide with a minimum height of 6.20 m. (20′ 4 1/8″). The tunnel has the usual railway section.

3. On the deep sections between the « Red Gate » and « Okhotny Riad » stations for a distance of about 2.50 km.

(¹²) The rate of conversion of roubles into French francs is given at the end of this article.

(1.55 miles) each track is located in a separate tube 5.10 m. (16′ 8 25/32″) inside diameter (fig. 14). These tubes are lined, as a rule, in concrete.

Where the tunnel had to be shield-driven, a reinforced concrete lining 0.50 m. (19 11/16″) thick was used.

It certain sections through perfectly stable soil, vertical side walls were used.

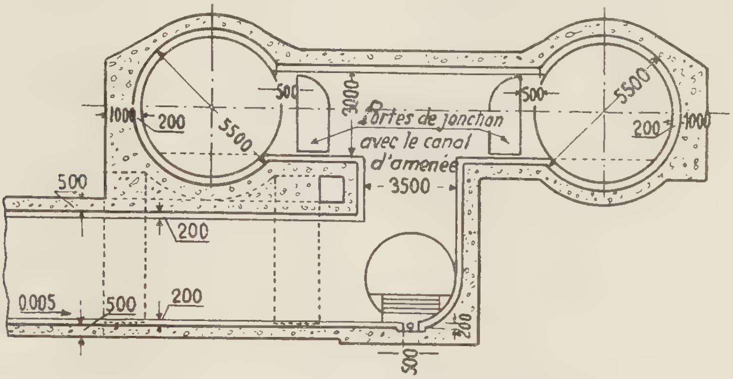

Fig. 14. — Section of two-tube underground line.

Note : Portes de jonction... = air current change-over doors.

VI. — Ventilation.

Particular attention was given to the ventilation of the tunnels.

The detailed investigations — which cannot be described here (13) — of the problem showed that of the three elements to be evacuated, carbon dioxyde, humidity due to the passengers, and heat from the passengers and electric motors, the latter is much the more important. The ventilating equipment was consequently designed to keep the temperature between a minimum of + 10° 6 (50° F.) in Winter and a maximum of + 25° C. (87° F.) in Summer.

Two ventilation systems are used :

1. In shallow tunnels with the two tracks in a common tube;

2. In deep tunnels with two tubes.

In the former method, ventilating shafts without fans are provided every 100 to 120 m. (110 to 130 yards) along the tunnel. In most cases these are the working shafts, which have been suitably equipped after the tunnels were driven. Their usual section is 4 m. × 1 m. (13′ 1 1/2″ × 3′ 3 3/8″), and the inlet or exhaust air passes through vertical grills as shown in the drawing (fig. 13).

There are in all 56 such shafts.

The fans in the special station entrance buildings draw in air from outside during the hot weather. This air leaves through the shafts just described. In cold weather (14) the fans are reversed and exhaust the air from the stations. The fresh air drawn down through the shafts is warmed by the heat given off by the trains.

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(13) A detailed article on the ventilation of the Moscow Underground was published by *Mr. Poliakoff* in the Russian Journal *Heating and Ventilation*. Most of the above details about ventilation have been taken from it.

(14) Hot and cold weather are not used here with any very precise meaning. The air current is reversed when the air temperature is about 0° C. (32° F.). The exact change-over temperature is determined by experience for each station.

The capacity of the fans varies from 60 000 to 100 000 m^3 (2 118 000 and 3 531 000 cu. ft.) per hour at the different stations. In cold weather only about half these quantities of air have to be exhausted.

Some details of the ventilating system at the « Communist Youth » station are shown in figure 8.

The ventilation of the deep tunnels with twin tubes is much more complex. 350 000 to 400 000 m^3 (12 360 000 to 14 120 000 cu. ft.) of air have to be introduced every hour in hot weather. The air is forced under the platforms by special fans and distributed along each tube into the direction the trains run. The used air is exhausted by fans in shafts located 2/3rds of the way to the next station. In cold weather, the air drawn in by the fans of these shafts is forced into the opposite direction but always in the direction the trains run, thus through a different tube to that used in Summer. It has, therefore, still to travel 2/3rds of the distance between two deep stations.

Consequently, all the fans have to be able to work in both directions, and each shaft has to be put into communication with either of the tubes connecting two stations. Figure 14 shows a ventilation equipment of this type and figure 15, one for a deep station.

It would, of course, have been better to have brought the air through mains above the tunnels; however, the very deep tunnels are generally located at the limit of the calcareous stratum, and for this reason the air mains are laid along the bottom of the tunnel, although this position has its drawbacks as regards drainage.

The fans in the Moscow Underground were built to drawings prepared by the Soviet Central Aerodynamic and Aviation Office (known as the ZAGI). The diameters are 1 600, 1 900 and 2 500 mm. (5′ 3″, 6′ 3 and 8′ 2 1/2″), and the blades are solid-cast aluminium. The air current is reversed by turning the blades 180°.

VII. — **Construction.**

The methods used varied with the type of tunnel under construction.

1. Most of the underground was built in open cut, the sides of the trenches being held by wood sheet piling. Metal shuttering was only used in the « Communist Youth » station, where there was a considerable inrush of water, the site being close to an old brook.

In the outer districts beyond the « Communist Youth » station, the roads were wide enough for the work to be done in open cut between the stations, without interfering with the road traffic. In the western part of the city between the « Soviet Palace » and « Crimea » stations, the road had to be closed whilst the work was in hand.

Most of the excavation work was done by shovel, the spoil being barrowed away. The lack of up to date material handling plant and powerful pumps is said to have interfered with the progress of the work (15). The cost was very high, as will be seen later.

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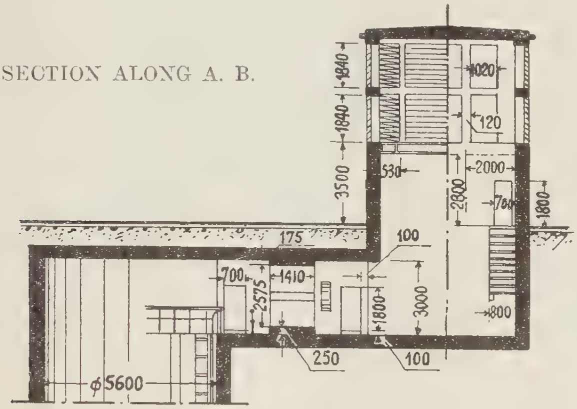
(15) A very detailed description of the construction of the Moscow Underground is given in the German review *Bautechnik* (publishers Wilhelm Ernst & Sohn, Berlin), in an article by GOERTZ, Nos. 33 and 35, 1934. Figures 18 and 20 (figs. 9 and 15 in the original) have been taken from this article.

The section near the « Communist Youth » station, at the intersection with the old brook mentioned above, can also be classified as done in open cut, although built in caissons.

Particular care had to be taken at this place where the Underground crosses the junction line between the railways to Leningrad and the South, carrying a heavy passenger traffic. Furthermore, the Underground at this point also passes close to a large building.

SECTION ALONG A. B.



PLAN.

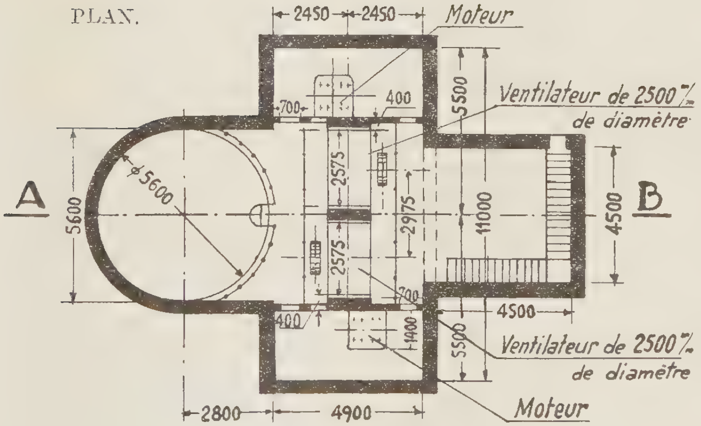


Fig. 15. — Ventilating equipment in a very deep station.

Each of the three caissons is 25 m. (82′) long and 11 m. (36′) wide. The distance between the caissons is 3 m. (9′ 10″), making the total length of the section 81 m. (265′ 10″).

The caissons were sunk a maximum depth of 22.33 m. (73′ 3″) below ground level, but as the caissons were erected in

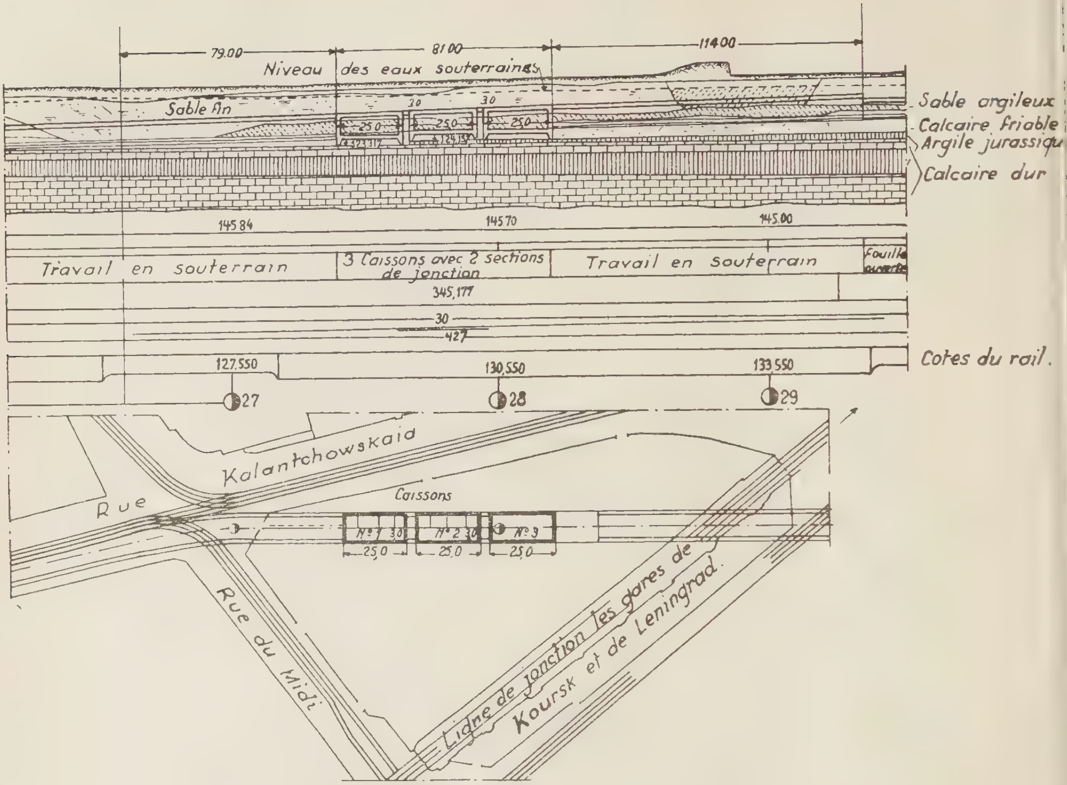


Fig. 16. — Arrangement of caissons near the « Communist Youth » station.

Explanation of French terms:

Niveau des eaux souterraines = underground water level. — Sable fin = fine sand. — Sable argileux = loamy sand. — Calcaire friable = brittle limestone. — Argile jurassique = Jurassic clay. — Calcaire dur = hard limestone. — Travail en souterrain = underground work. — 3 caissons avec 2 sections de jonction = 3 caissons with 2 intermediate sections. — Cotes du rail = height of rail above sea level. — Ligne... Leningrad = junction line between the « Kursk » and « Leningrad » stations.

an excavation 5 m. (16′ 5″) deep, they had to be sunk only 17.33 m. (56′ 10″), only the last 12 m. (39′ 4 1/2″) being through water, the water level being 10 m. (32′ 9″) below ground level at this point.

Each caisson took 105 000 man-hours to sink, involved the excavation of 694 m³ (908 cu. yards) of material, and took 1 750 m³ (2 289 cu. yards) of reinforced concrete, 250 m³ (327 cu. yards) of ordinary concrete to fill the chamber, and 94 tons of steel. Each caisson took 36 days to sink (16).

2. The deep tunnels, both single and double-track, were driven in the usual way. The Belgian method was adopted. A top heading was driven first of all, the roof was then built, and the lower

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(16) This information and the drawings, figures 16 and 17, have been taken from the article by BLUMFELD, in the German review *Bauingenieur*, page 411, 1935; publishers, Julius Springer, Berlin W 9.

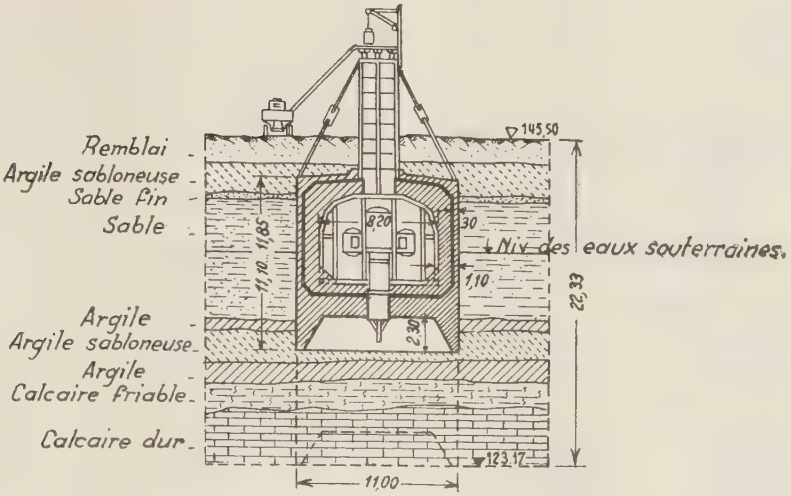

Fig. 17. — Cross section of a caisson.

Explanation of French terms:
Remblai = fill. — Argile sablonneuse = sandy clay. — Sable fin = fine sand. — Calcaire dur = hard limestone. — Niveau des eaux souterraines = underground water level.

parts of the tunnels driven under it.

The tunnel was driven from shafts 15 to 40 m. (49′ to 131′) deep, there being 40 such shafts at an average distance of 100 m. (109 yards) apart.

The greatest difficulty experienced was when sinking the shafts through the water bearing stratum, and not in driving the tunnels which in most cases were in sound ground.

So as not to endanger the neighbouring large blocks of flats, eight of the shafts were sunk by compressed air, and shaft No. 20*bis* near the Red Gate by freezing. As this process is still little used, we will give more details about it.

The depth of shaft No. 20*bis* to the limestone is 28 m. (92′). The ground is first of all frozen to a depth of 1 m. (3′ 3 3/8″) round an annular excavation 6 m. (19′ 8″) outside diameter and 3.30 m. (10′ 10″) inside diameter, after which the centre part is removed (fig. 18). The shaft, during this work, was lined out with I steel hoops spaced 1 m. to 1.20 m. (3′ 3 3/8″ to 3′ 11 1/4″), and held in position by round timbers 5 cm. (2″) in diameter. This temporary lining was afterwards replaced by the permanent reinforced concrete lining (17). The air temperature inside the shaft was about 0° C. (32° F.) (at the end of August 1933), but the temperature of the frozen ground was -10° C. to -12° C. (14° F. to 10.4° F.). The concrete was heated electrically to make it set properly.

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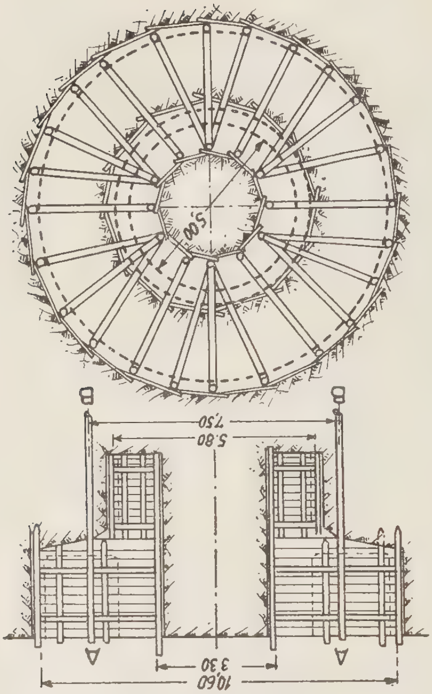
(17) It would have been simpler to have fitted the permanent steel or cast iron straight away. But as this material is amoungst those there is a shortage of in the U. S. S. R., it was decided to line with reinforced concrete although it made the work more complicated. It is surprising to learn that in such a country as Russia there could be any question of shortage of steel and cast iron to the extent of the small weight wanted to line a 28 m. (92′) deep shaft.



A B : Freezing pipe.

Fig. 18. — Shaft 20*bis*.

Figure 19 shows the reinforcement in the ferro-concrete linings 0.30 m. (11 13/16″) thick and the position of the heating electrodes ; 65-volt current was used. The concreting was done by sections 1 m. (3′ 3 3/8″) deep between two of the I bar hoops mentioned above. The work took 8 days, during which 120 m³ (147 cu. yards) of concrete was used, the work going forward without a break.

The mobile platform on which the men worked almost completely isolated the part of the shaft already concreted. The temperature in the section so isolated was as high as 32 to 35° C. (89.6 to 95° F.), whereas above it was only + 1 to 3° C. (33.8 to 37.4° F.) Owing to the good insulation of the outside face of the concrete and the fact that the already concreted part was tightly enclosed, electric heating was discontinued 24 hours after completion of the concreting, with the result that the current consumption was only 50 kw-h. per m³ (38 kw-h. per cu. yard) of concrete (18).

The freezing process was also used for driving the inclined galleries for the escalators in some of the deep stations and these galleries have been lined out in cast iron.

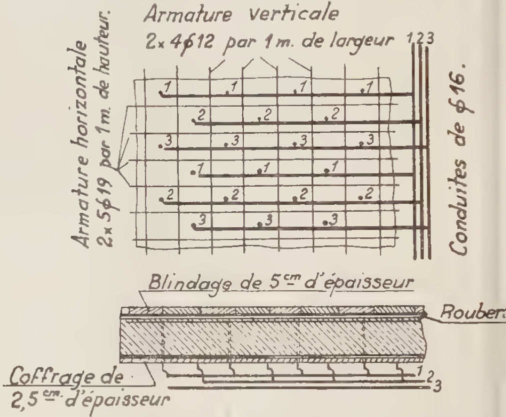

Armature verticale
2×4ϕ12 par 1m. de largeur
1 2 3
Armature horizontale
2×5ϕ19 par 1m. de hauteur.
Conduites de ϕ16.
1
2
3
Blindage de 5cm d'épaisseur
Rouber
Coffrage de 2,5cm d'épaisseur

Fig. 19. — Electric heating of concrete.

Explanation of French terms :

Armature... hauteur = horizontal reinforcement : 2 bars, 3/16" diam., 19 per metre (3' 3 3/8") of height. — Armature verticale... = Vertical reinforcement : 2 bars, 5/32 diam., 12 per metre (3' 3 3/8') of width. — Conduites de Φ 16 = 5/8" Φ pipes. — Blindage de 5 mm. d'épaisseur = 13/64" thick sheeting. — Rouberoide = Rubberoid. — Coffrage de 2.5 cm. d'épaisseur = Shuttering, 1" thick.

At certain points under Miasnitzkaia Street, the quicksand at the top of the tunnel was consolidated by chemical means. The advantage of this method is its speed, as the ground gave a resistance of 20 to 60 kgr./cm² (285 to to 850 lb.

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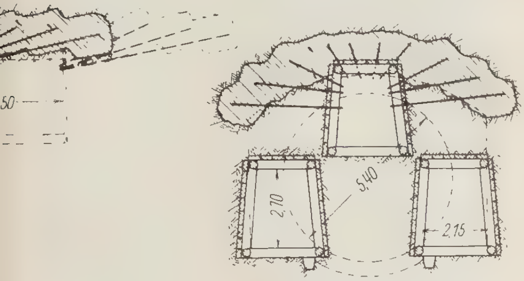
(18) This information, and figure 19 showing the electric heating, are from A. RETHY'S article in the German review *Beton und Eisen*, 1934, p. 58, published by Wilhelm Ernst & Sohn, Berlin W 9.

per sq. in.) and even 250 kgr./cm² (3 550 lb. per sq. in.) in 15 to 20 minutes, although there was much quartz present.

Figure 20 shows diagrammatically how the work was done in conjunction with the chemical process.



20. — Chemical consolidation of quicksand.

3. The work at the intersection of the tunnel with the Neglinnaja brook, canalised in 1820, had to be done with the shield, owing to the particularly wet nature of the ground. The shield in question was ordered in England.

The length of each of the shield-driven tunnels was about 360 m. (394 yards).

The official Russian description only gives meagre details on the progress of this work, the maximum rate of progress being given as 4.75 m. (15′ 7″) per day and the average 2.40 m. (7′ 10 1/2″ in.) (19).

The air pressure in the working chamber was 2.3 kgr/cm² (32.7 lb. per sq. inch.).

The work was completed without accident and without the slighest damage to the neighbouring buildings although the shield passed close to the Moscow Dramatic Theatre, over a century old, the Metropole Hotel, and other large buildings.

VIII. — Track.

The rails are the heaviest now being rolled in Russia and weigh 45.4 kgr/m. (91.6 lb. per yard). They are laid on 1 600 sleepers per km. (2 575 sleepers per mile) on straight sections, and 1 760 (2 832 per mile) on curves.

The gauge is the standard Russian of 1 524 m. (5 ft). The section of the sleepers is 250 × 160 mm. (9 27/32 ″ × 6 5/16″), and their length 2.70 m. (8′ 10 5/16″). They are creosoted.

The track in the stations is laid on wood blocks embedded in the concrete, as shown in figure 7. Between stations the track is carried on a layer of granite ballast 30 cm. (1′) thick under the sleepers. The ballast was brought from the Dnieper quarries in Ukraine, about 1 000 km. (620 miles) from Moscow.

The conductor rail is the same section as the track rails but is made of mild steel to give better electrical conductivity. It is carried on insulators 5 m. (16′ 5″) apart.

The total length of line now in service is 35 km. (21.7 miles), 3 km. (1.86 mile) being service sidings and connections.

IX. — Electrical equipment.

The 6 600-volt alternating current is generated by the « Mosenergo » power station in Moscow, and is transformed into 825-volt direct current in four substations near the « Sokolniki », « Red Gate », « Okhotny Riad » and « Crimea » stations. The total substation capacity is 14 800 kw., but can be increased to 90 000 kw., with 48 000 kw. in the « Okhotny Riad » substation, without altering the buildings.

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(19) This speed cannot be said to be very great. As a comparison each of the tubes of the Paris Nord-Sud line was driven at the rate of 1.50 m. (4′ 11″) and line N 8 under the Seine. Place de la Concorde, 1.31 m. (4′ 3 1/2″). This was in 1908 and 1910.

As regards more recent work, the 1 043 m. (0.64 mile) long tunnel under Boston Harbour, 9.30 m. (30′ 6″) diameter was built between August 1931 and April 1932, the average rate of progress being 4.60 m. (15′ 1″) per day and 163.50 m. (339 1/2′) per month.

The central distribution plant is at the « Okhotny Riad » substation.

The current for lighting and automatic signalling and for working the mechanical escalators and the other auxiliary equipment is taken from substations in each of the stations other than the « Lenin Library » station.

X. — Rolling stock.

The rolling stock includes both motor vehicles and trailers. The station platforms are long enough for eight-coach trains including 4 motor coaches. When first opened, half sets of 4 vehicles will be used.

The coaches are 18.90 m. (62′) long over buffers, 2.70 m. (8′ 10 5/16″) wide, and the interior height is 2.60 m. (8′ 6 3/8″) (fig. 21). The motor coaches weigh 45 t. (44.3 Engl. tons) and the trailers 31.5 t. (31 Engl. tons).

The motor coaches are equipped with four 150-kw. motors each. They are fitted with Matrosoff electro-pneumatic brakes and electric heating. The four-wheeled bogies have 0.90-m. (2′ 11 1/2″) diameter wheels, and a wheel base of 2.315 m. (7′ 7 5/32″).

Four automatically-operated doors 1.20 m. (3′ 11 1/4″) wide are fitted in each side of each body. The doors can only be opened when the train is stopped; the train cannot be restarted until all the doors are closed.

The coaches have longitudinal upholstered leather-covered seats (fig. 22). They have 52 seats and room for 118 standing. Although longitudinal seats are less comfortable, they allow of the full carrying capacity of the vehicles being taken advantage of during rush hours.

The maximum axle-load (vehicle and paying load) is 17.5 t. (17.2 Engl. tons).

XI. — Operating conditions.

The signalling of the line is based on a 3-minute headway between trains. This time is considerable in comparison with

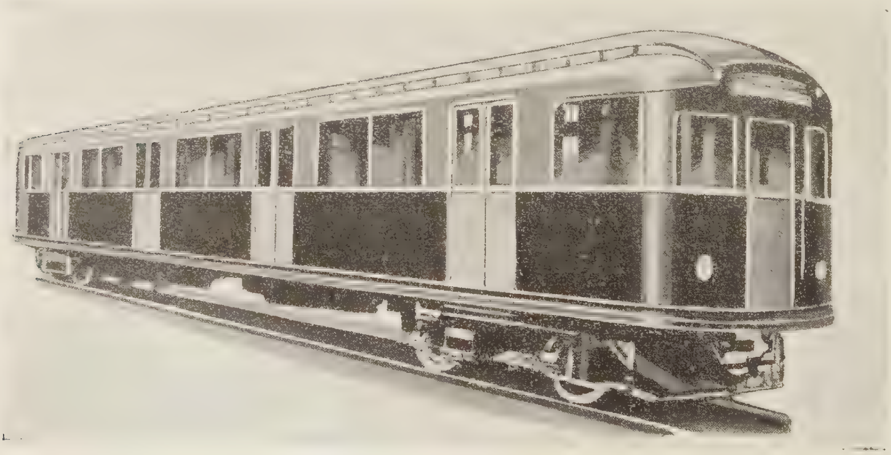

Fig. 21. — Outside view of a carriage.

1 minute 30 seconds on the busiest Paris lines and 7 minutes on the least used sections during the slackest period. The traffic capacity with rakes of 8 vehicles is therefore $\frac{170 \times 8 \times 60}{3} = 27\,200$ passengers per hour in each direction, if all places be occupied (21). In practice a greater number of passengers can be carried during rush hours, by overloading the carriages, as for example up to 50 % in Paris.

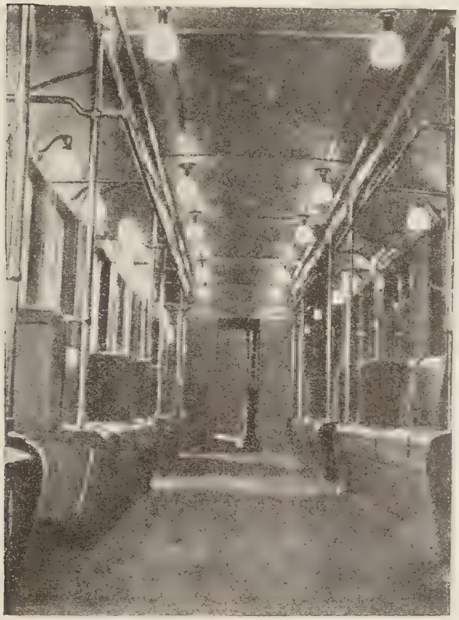

Fig. 22. — Interior view of a carriage.

The maximum train speed on the straight sections on the level or easy gradients is 60 km. (37.3 miles) per hour, as in Paris. The commercial (overall) speed should be 26.6 km. (16.5 miles) an hour (22), but obviously it cannot yet be stated if it will reach this figure in ordinary working.

The present price of tickets in Moscow is 40 kopeks for a single journey and 35 kopeks if books of 10 or 20 tickets are bought. It is difficult to say what these prices mean to the Moscow people, but it should be high seeing the monthly wages of a workman are about 150 roubles.

XVI. — Time taken to build the line and cost.

The first Underground line was opened to service on the 15th May, 1935, or about six months later than expected. The work was begun at the end of 1932, and the provisional opening date was the 19th February 1935. The work properly speaking took 26 months, after which there was a period of transitory working which lasted some three months (23).

The new lines mentioned above were begun in April 1935 and should be opened to service at the end of 1937. The work, if not delayed, will therefore last about 2 1/2 years.

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(21) The capacity of the busiest lines of the Paris Metro, with trains at 1 1/2-minute intervals, is 24 000 passengers in each direction. It will be increased to 31 600 after lengthening the platforms to 105 m. (343′) and making up the trains of 7 carriages.

(22) The overall speed in Paris, at the present time, is 24 km. (14.9 miles) an hour.

(23) It may be remembered that the Paris Metro line No. 1, 10.32 km. (6.4 miles) long, was started at the end of 1898 and opened to traffic on the 19th July 1900, a period of 20 mounths against the 29 months taken to do the same work in Moscow, though the former was built 35 years ago, when the machinery available was not so powerful and there was much less experience in such work.

The cost of the first lines was as follows :

	Millions of roubles.
Tunnels, stations and passage-ways.	506.2
Interior linings of stations and entrances	28.0
Track	14.4
Signalling.	4.5
Mechanical escalators	15.0
Mains and electric conductors.	7.2
Ventilation and lighting equipment.	4.8
Traction- and other substations.	13.0
Workshops and sheds.	12.8
Rolling stock	20.0
Total expenditure other than on the main works (tunnels, permanent way).	119.7
Total.	625.9

The 11.4 km. (7.1 miles) of line in service, therefore, involved an expenditure of 55 000 000 roubles per kilometre, of which 44 300 000 represents the tunnels and permanent way proper.

This cost must be considered as high, seeing that the corresponding figures in Paris, when in 1900 the lines were opened to traffic, were only 4 000 000 francs of which 2 700 000 for the tunnels, equivalent to 20 and 13.5 million present-day francs.

The more recent Paris line [No. 11 line (extension of lines 7, 8, 9, and 10)] cost much more, namely 40 000 000 francs per kilometre.

This increase is explained not only by the increase in unit prices, but to a large extent by the complications of the transfer stations such as « Châtelet » and « République ». There were no such stations on the Paris No. 1 line in 1900, nor are there on the lines in service in Moscow. The figures for Berlin (24) are almost the same as for Paris, as the construction of these lines was begun at about the same time. The first line 10.6 km. (6.6 miles) long, opened in 1902, cost 2 635 000 marks per km. excluding the substations and rolling stock, or 3 260 000 francs of the period, or approximately the same as in Paris.

The price per km. of the 13.4 km. (8.3 miles) of lines built in Berlin after the deflation, in round figures was Rm. 7 820 000 under the same conditions as the lines mentioned above, or 47 500 at the official rate, which is really 33 % higher than the true rate. Using the latter value the cost per km. in francs is about 35 000 000 or almost exactly that of the Paris lines, seeing that this amount does not include certain items contained in the Paris figures.

It is difficult to convert roubles into francs. When the work was in hand the exchange was 13 French francs to the rouble. It is now fixed at 3 francs, which is still too high and does not correspond to the purchasing power of the rouble. For example the price of bread per kgr. is 2 roubles in Moscow and 1.6 francs in Paris.

In calculating the cost of labour, a much higher rate must be taken. The average monthly salary of the workmen, in 1931, was 150 roubles, whereas on the French main-line railways it was 1 111 francs. As the cost of labour on the Moscow Underground was 45 % of the total cost (25) we can get an idea of the cost of building the underground railway by converting roubles into francs, at an artificial rate which however corresponds more or less with the actual position, as follows :

$$\frac{1111}{150} \times 0.45 + \frac{1.6}{2} \times 0.55 = 3.33 + 0.44$$

= 3.77 or 3.80 French francs to the rouble.

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(24) The information on the Berlin Underground is taken from BOUSSET's book *Die Berliner U. Bahn*, 1935, published by Wilhelm Ernst & Sohn, Berlin W 9.

(25) From information given by BOUSSET, *Die Berliner U. Bahn*, p. 135.

Converting the cost per km. i. e. 55 000 000 roubles at this rate, we get 209 000 000 French francs or five times the cost of the most recent Paris and Berlin lines.

The labour cost on the Moscow Metro can also be compared with the corresponding expenditure on other such railways by considering the volume of the work done.

Up to the 1st March 1935, 16 270 000 men-days were worked with a daily average, in 1934, of 64 685, 4 300 or 6.7 % of which refers to the engineers and other technical employees. The principal work done by this labour was the excavation of 2 295 000 m³ (3 million cu. yards) of spoil in various kinds of ground and the building in of 842 000 m³ (1 101 300 cu. yards) of concrete and reinforced concrete. There was therefore 0.367 cubic metre of concrete and reinforced concrete work per cubic metre of excavation.

The labour including all other work amounted to 7.1 working days per cubic metre excavated.

Corresponding data is not available for the other Underground systems ; only quite exceptionally are such data published. We can, however, use the data for the Hauenstein tunnel, in Switzerland, with sufficient accuracy for our purpose. This tunnel is 8 434 m. long (26), it represents 485 000 cubic metres of excavation in various soils and 95 000 m³ of masonry. The work, including the various supplementary items, involved 1 270 212 working days or 2.52 per m³ excavated, or only 37 % of the labour used in Moscow.

Besides the expenditure given above the official Russian figures still show an expenditure of 130 000 000 roubles for auxiliary works, mechanical equipment and tools, as well as for building houses and educational centres. As the purport of that expenditure is not clear, we have not included it in the cost per kilometre, although part of it should be added to the 209 millions to make more accurate the comparison with the cost of building metropolitan railways in the capitals of Western Europe.

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(26) « Der Bau des Hauenstein-Basistunnels », 1912-1915, *Denkschrift des Sektionsingenieurs;* E. WIESMANN*;* Berlin and Berne.

[625. 13 (09 (.42)]

Building the Severn tunnel,

by the late Ernest BENEDICT (*), M. Inst. C. E.

(*The Railway Gazette*, Great Western Centenary number).

The original idea of making a tunnel to supersede the steam ferry across the River Severn occurred in 1862 to Mr. Charles Richardson while he was engaged on the New Passage ferry piers then being built for the Bristol and South Wales Union Railway. His preliminary observations satisfied him of the practicability of a tunnel roughly on the line of the ferry, and on bringing the matter before M. Leonard Bruton, Secretary of the Bristol and South Wales Union Railway Company, a Bill was deposited in Parliament, in 1863, by a Bristol company, under practically the same management as the Union Railway. After two attempts to pass the Bill, which failed for want of funds, the Great Western Railway took up the scheme, and with its backing, the Bill was again deposited in 1872, and in spite of some opposition an Act was obtained, mainly on the strength of the favourable evidence of Sir John Hawkshaw, who was appointed Consulting Engineer for the work.

The plan shows the portion of the Severn estuary adjacent to the original ferry and the new tunnel, with the lines of the ferry and tunnel, and connections therewith on the English and Welsh sides. The west edge of the English stones and the east edge of the Lady Bench Rock are the boundaries of the Shoots, which are 1 200 ft. wide, and 95 ft. deep at high water. The English stones are dry at half-tide, and are of such hard marl that they have resisted the action of the river. The range of tide at the crossing amounts to 50 ft. at extraordinary H. S. T., the flood comes up in five hours, and the ebb recedes in seven hours, with 20 minutes' slack water at each turn of tide. The flood water pours over the English stones, and at the ebb, as the water goes down, it runs out into the ferry channel and so around into the Shoots, which then attain a velocity of 10 knots. Mr. Richardson's observations had satisfied him that a tunnel could be driven at this place without any danger from the river water, owing to the closeness of the strata through which it would pass.

In the Act of 1872 the limits of deviation across the Shoots were widened to 300 yards, and careful soundings between these limits were taken before the centre line was fixed. Thirty-one cross sections were taken, at 10 yards apart, and with a special machine is was possible to take soundings of the full depth within 3 inches, and at points as near as possible to each other, which were

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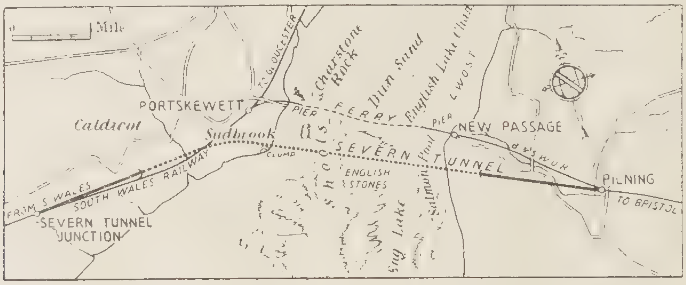
(1) This article has been preserved for many years in the files of *The Railway Gazette*, for which it was specially written when the author was a member of its editorial staff. Julius Felix Ernest Charles (known as Ernest) Benedict, was born in 1838 and was a son of Sir Julius Benedict, the well-known conductor and composer. After being educated in London, Naples, Pisa, and Paris, he was apprenticed for three years (at the suggestion of Isambard Brunel) to John Scott Russel, who was then building the steamship *Great Eastern* at Millwall. After a little over a year Brunel took Benedict into his own office. From 1859 to 1864 Benedict was Assistant Engineer during the construction of the Bristol and South Wales Union Railway. From October, 1865, he served with the Eastern Bengal Railway, and thus began a distinguished career in connection with Indian railway engineering. During his later years he devoted much of his time to journalistic and literary work, and died on December 1, 1925, at the advanced age of 87. (Edit. *Ry. Gaz.*)

only 2 ft. apart on the final centre line. It took three months to do this work, no signs of any crevice at all were discovered, and this settled the final lay-out of the tunnel.

At the English portal it was necessary to provide protecting banks to keep the high flood water out of the working excavations, and ultimately out of the tunnel, and with this view, sea banks were constructed 16 ft. high. Mr. Richardson decided that a 30-ft. cover under the Shoots was sufficient, and sent in his estimates accordingly, with approach tunnels graded at 1 : 100 on both the English and Welsh sides, the new works extending from Pilning station on the Bristol and South Wales Union Railway, to Rogiet station on the South Wales Railway, a total distance of 7 miles.

From 1863 to 1865, as his assistant, the present writer worked under Mr. Richardson in all the preliminary observations, and in 1871, while on leave from India, he had charge of the sounding party in the Shoots.

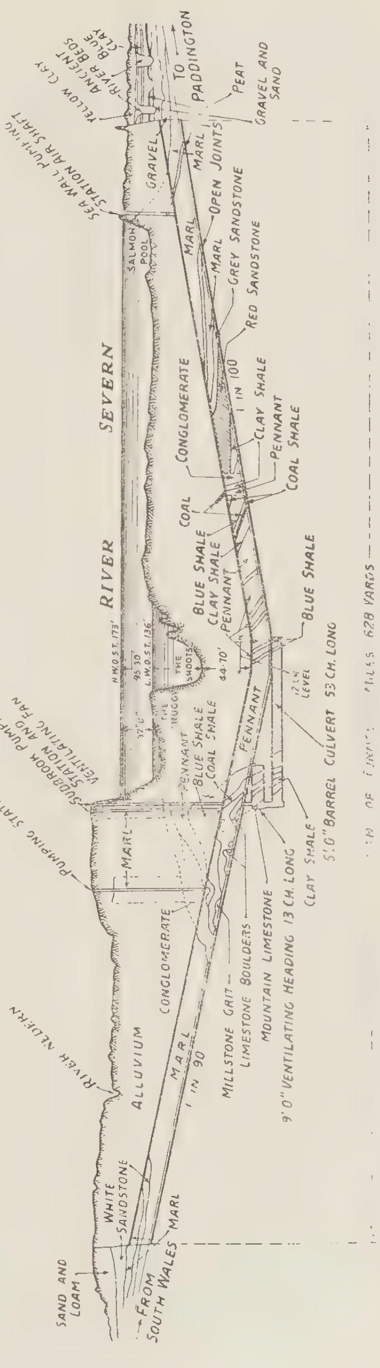


Sketch plan of the Severn tunnel site.

On March 18, 1873, work on the tunnel was begun by the Great Western Railway, departmentally, under Mr. Richardson, by sinking a shaft 15 ft. diameter, and 200 ft. deep (called the Old shaft) at Sudbrook, on the western bank, from which a drainage heading, 7 ft. square, rising 1 : 500 was driven eastwards to the intended lowest point of the tunnel. In four and a-half years this heading was driven 1 600 yards, to a point just across the Shoots, and progress being slow, the Great Western Railway directors decided to invite tenders for the completion of the work. Three were received, all too high in the opinion of the board which decided thereupon to continue upon the old lines, additionally letting contracts for the sea-bank shaft on the English side, and Marsh and Hill shafts on the Welsh side. The contracts also included the driving of headings eastwards and westwards from each of these shafts, the railway company continuing with the under-river heading.

During 1879 top headings eastwards and westwards were started from the Old Shaft. These had progressed a certain distance when on October 18 a spring was tapped at the western end, at a time when the ends of the meeting headings were only 138 yards apart. This flooded the under-river work on the Sudbrook side up to tide level. On the accident being reported to the Chairman of the Great Western Railway, Sir Daniel Gooch, who was at the opening of the Midland Railway's new Severn bridge at Sharpness, he recommended that the work should be placed directly under Sir John (then Mr.) Hawkshaw, and this was done. Mr. Hawkshaw informed the directors of the Great Western Railway that he was prepared to act as Chief Engineer provided that they would permit him to let the construction contract himself, and on this being agreed to, he arranged with Mr. T. A. Walker, who had previously executed work under him, to enter into the contract for the completion of the tunnel, the final arrangements for which were signed on December 18, 1879.

At this time all workings from the Sudbrook shaft were flooded owing to the irruption of the Big Spring. A clause in the contract provided that the portion of the tunnel under the Shoots should first be proceeded with, as the railway directors and the engineer still thought the chief risk lay in this portion and, consequently, the first thing to be done was to clear the workings of water. The Great Western Railway had bought two specially large pumping engines immediately after the Big Spring had broken in, and these had to be installed and got to work; meanwhile the problem was to shut off the Big Spring from the pumping shaft. The heading through which the water rose in the shaft was 140 ft. below the normal level, and the contractor's idea was to lower two shields down to this heading, and securely strut them across the shaft. The difficulty in the operation lay in the fact that the whole of the work was under water, and that the placing and strutting of the shields had accordingly to be performed by divers. The pressure of water at the working place was so great that very few men could sustain it, and the existing pumps were therefore put to work, and the head of water reduced by 50 ft. A great deal of trouble was experienced with the pumps, but finally the two shields were placed and strutted, when it was at once found that the western, or Welsh side, portion — the one adjacent to the Big Spring — was leaking badly all round. A quantity of Portland cement was introduced through doors in the shield, and built up inside to try to check this leakage, but it soon became evident that the effect of these was but little, and as the existing pumps could not deal with the large quantity of water coming through, it was decided to abandon the attempt to pump out the shaft until the new 38-in.



Sectional diagram of the Severn tunnel.

pump which had been ordered by the Great Western Railway could be started.

In the meantime, Mr. Hawkshaw had decided to lower the tunnel under the Shoots by 15 ft., to ensure greater security with the under-river portion, and in order to effect this the grading of the line, which had previously been arranged as 1 : 100 on both sides of the bottom level, was amended to 1 : 90 on the Welsh side, the English side remaining at 1 : 100. Following this decision, a further pumping shaft was sunk at Sudbrook, adjacent to the Old shaft;the Sea-Wall shaft was lowered 27 ft., partly to allow for the re-graded railway, and partly to provide a sump; and two other shafts were arranged for west of Sudbrook, so as to enable a start to be made with the work clear of the point where the Big Spring had irrupted.

Early in June 1880, the work of lowering down the Old shaft the new 38-in. pump was begun, but when nearly in position, it was found that it fouled a column which was part of the supporting structure of the old pumps. This obstruction could not be readily removed, and it was therefore decided to start the pumping in the position which had been attained and things were going on well, the water having been lowered to within a few feet of the bottom stage, when the new pump suddenly broke to pieces, and in a few hours the shaft was again full of water, and the general state of things was in the same position as seven months before. The breakdown of the pump was found to be primarily due to the design of the valves and seatings, but in view of the general damage caused, the whole pump had to be withdrawn, and in the replacement, the working diameter was reduced to 35 in. The renewed pump was started again on October 14, 1880, and this time the water was gradually lowered, but it was found that there was hardly sufficient capacity to deal with it completely, and it was therefore decided to put additional pumps in position. The water was finally lowered to such a point that it was possible to explore the western heading. A suitable spot was found where it was decided to make dams to shut off the water of the Big Spring, and these were immediately successful in holding back this troublesome inrush.

The success of these final manœuvres in dealing with the Big Spring was due almost entirely to the diver, Lambert, who was engaged on the work. Mr. Richardson's description of him is brief and pointed : « His name is Lambert, a fair-haired man of few words, but of great courage. » In his earlier submarine operations at the tunnel he was using the orthodox diving outfit, which entailed great trouble and danger due to the air pipe entangling itself with the debris in the shaft and heading, and, as a result, Mr. Walker obtained the services of Fleuss, who was then exhibiting in London his new apparatus for diving without pipes. Fleuss, however, after one experience, refused to attempt further, so Lambert suggested the loan of the dress to himself. After much controversy this was agreed, and enabled Lambert finally to reach and shut the door of the heading to check the Spring.

After this feat had been accomplished, progress was soon made with enlarging the existing headings from the Old shaft to allow for double lines of 21-in. gauge railway. At the Sea Wall shaft, the tunnel proper was under construction, when water burst in through the roof, and to the consternation of the workmen proved to be salt water, showing that it came from the river. To find the leak, which was adjacent to the Salmon Pool, a number of men arranged to join hands and walk through the water — the argument being that when one disappeared, the leak was found. This actually happened, and at low water the hole was effectually stopped by layers of loose clay and bagged clay alternately, the final covering layer being a large quantity of bagged clay.

Work from the Sudbrook shaft was proceeding tolerably well and, as this shaft had to handle the bulk of the material, heavier track was laid, concurrently with a good road and proper drainage, in addition to which it is worth noting that electric lighting was installed (in 1881). Ventilation of the workings was by compressed air, from Sudbrook, this air having to be conveyed 1 3/4 miles at the extreme point. Three mains were in position, one 2 in for the men driving the heading, and two 3 in. for power for the rock-drills. A large fan, 18 ft. dia., was fixed shortly afterwards, consequent upon the deaths of two men which were popularly ascribed to the fumes given off by the blasting material, known as « tonite ». The 18-ft. diameter Guibal fan referred to worked quite satisfactorily during the tunnel construction, and the same system was adopted for the permanent ventilation, a 40-ft. diameter fan replacing the smaller one.

In 1882 instructions were received that work was to be proceeded with at all points, and a start was therefore made on the approach cuttings at each end. Towards the end of February in that year, the chief engineer passed through the whole of the heading under the river, from which work could be seen in all stages of progress. The electric light system was also introduced on the Gloucestershire side, with 2 000 candle-power lamps, and extended on the Sudbrook side to include the surface works. A further interesting matter at this time was the installation of a telephone between the two ends of the tunnel works.

About the middle of 1883 it was decided to attempt the district in which the Big Spring had previously broken in, and it was decided to open the door in the head-wall which had been built across the heading in 1880. This was found difficult owing to the quantity of material which had been forced behind it, and finally this material had to be removed by a heading driven around the door. A great cavity was found from which this material had fallen, and great endeavours were made to fill this and support its roof. However, while this work and the advancement of the adjacent headings was proceeding, the Spring broke in again and flooded the whole of the tunnel workings. A large portion of the tunnel west of Sea-Wall shaft was then finished, and it was considered necessary to build across this a head-wall to check the flood. It was estimated that water was pouring into the workings at the rate of 27 000 gallons a minute, which was approximately two and a-half times the capacity of the pumps which had to deal with it. After some trouble, divers succeeded in closing the door of the head-wall, and shortly afterwards the pumps cleared the water. Unfortunately, a few days before this record high tide had flooded the Marsh Pit (west of Sudbrook) and all the workings connected with it, and also the cutting. However, this water was gradually cleared, and the Big Spring given a further check in the shape of a large head-wall of brick and cement built across the full-sized tunnel, 260 ft. west of Sudbrook shaft.

This spring presented the great problem at this time as it was now obvious that a continuous volume of water had to be dealt with. At one time it was thought that a subterranean reservoir had been tapped, which could gradually be pumped off as it drained into the workings, but the last irruption had indicated sufficiently that this assumption was unsound. Before the tunnel could be completed this volume of water would have to be dealt with, and it was therefore decided to increase the pumping capacity as rapidly as possible. Additional boilers and the corresponding boiler-house accommodation had also to be provided, which necessitated further heavy expenditure. Meanwhile the whole of the tunnel was in progress, except 300 yards in the vicinity of the Big Spring, over 3 600 men were employed, and nothing of note had to be recorded. To deal with the spring it was decided to drive a side heading parallel to the centre line of the tunnel, from the Old Shaft at Sudbrook to the point where it would intercept the spring water. Meanwhile, as it was known that much of the water came from the loose bed of a small river in the locality, a concrete invert was constructed in this for a length of four miles. On December 19, 1884, the spring was tapped by the side heading, and the tunnel in the district left almost dry. The complete passage through the affected area had been completed just prior to this on October 17, and Sir Daniel Gooch happened to be on the workings at the time the through way was finished. The laying of the permanent way was commenced about this time on the Gloucestershire side of the river. The last length of the tunnel brickwork was keyed up on April 18, 1885, and the Big Spring afterwards imprisoned (it was thought finally) by closing the side heading. The first train, including in its passengers Sir Daniel Gooch, was run through the tunnel from Severn Tunnel junction on September 5, 1885, and after the trip it returned to the Monmouthshire side, as the junction connections at the other end were not complete.

The Big Spring had not, however, finished troubling the work, as the pressure on the brickwork of the tunnel, caused by the imprisonment of such head of water, had caused the bricks to break, the water shooting through the broken bricks right across the tunnel. In Mr. Richardson's monograph on the tunnel he claims the explanation of this to be comparatively simple, as he points out that the top ring of the invert (which portion of the brickwork, being the lowest, had to stand the highest water pressure) was the least leaky of all the six rings which were in place, and consequently the pressure leaked through the ofter five, and concentrated on the final layer. He calculated that the pressure was probably more than 2 tons per sq. in., with the result that the cement joints yielded, and the ring was blown up. As confirmation of this assumption, Mr. Richardson points out that no crushed bricks were found.

The pressure on the top of the tunnel due to the spring water was 52 lb. per sq. in., and on the bottom, 64 1/2 lb. per sq. in. In view of this new development, Mr. John Hawshaw decided to pump the whole of the water of the Spring and thus take the pressure off the brickwork, and to this end arrangements were made for a large additional shaft at Sudbrook, with pumping plant capable of dealing with a volume of water well above any known maximum that had so far been handled on the work. In due course most of this additional plant was in working order, and regular goods traffic through the tunnel was begun on September 1, 1886. The Board of Trade made an official inspection on November 22, 1886, stating in the report thereon that the total pumping capacity at five shafts was then 38 000 000 gallons of water a day, to pump between the known minimum and maximum of 23 000 000 and 30 000 000 gallons a day. When the whole of the plant was completed, the inspector stated that the pumping capacity would be 66 000 000 gallons a day. All the water from the Big Spring, except a small amount used for boiler feed, is pumped into the River Severn.

Passenger traffic was inaugurated on December 1, 1886, on the 7 mile 34 chain section between Pilning junction and Severn Tunnel junction which includes the 4 miles 628 yards of tunnel proper, constituting then, and still, the longest (1) railway tunnel in Great Britain. On the same date the 2 miles 59 chains from Pilning junction to New Passage pier, and 74 chains from Portskewett to the pier were closed.

(*) At the present time the Severn tunnel is the 25th in length among the world's long railway tunnels. (Ed. *Ry. Gaz.*)

[625. 24]

Recent developments in goods wagon construction,

by J. SCHINKE, Reichsbahnrat, Berlin-Steglitz.

(From *Glasers Annalen*).

After a brief retrospective description of the present-day goods wagon stock of the Reichsbahn, made up of wagons belonging to the former German States, of the Union type, and of the common user type, the author describes the development of welded wagons. He then gives particulars of recent designs of wagons for fast trains, and of the steps taken to improve the running of the other wagons. The article ends with a description of the progress made in special wagon design, such as high-capacity coal, mineral and mixed (coal and sand) wagons, as well as container flats, refrigerators, and wagons for conveying sick animals.

1. — Short retrospective review of development up to 1933.

The present stock of goods wagons represents four stages of evolution, the first and oldest being represented by the types *of the former German States;* they sometimes differ widely from one another, even within a particular class of stock.

This state of affairs only came to an end in February 1909, when the goods wagon committee of the newly instituted Rolling Stock Union of the German State Railways published uniform regulations on the dimensions of wagons and the design of their parts, such as wheels and axles, buffers, axle boxes, springs, etc..., which the member railways had to adopt. This was the origin of the *standard Union wagons,* the description of which includes the letters A_1 to A_{11}; for example the G wagon has the prefix A_2, and the Om wagon A_{10}. The first batches of these standard wagons were built in 1911 tot 1914.

However, when all the classes were taken into account, there still remained 180 different designs (1). This explains why the builders and even more so the repair shops insisted upon the reduction of the number of types, standard building methods, and absolute interchangeability. A considerable amount of preliminary work had to be done to meet these desiderata (2). The Om was the first wagon to be built in accordance with this principle of *interchangeability,* and was followed at brief intervals by other classes, the O wagon finishing the series in 1928.

The last and most up-to-date stage of development is represented by the welded wagons of recent construction.

2. — Evolution of goods wagons since 1933.

The main developments of the last few years have been the introduction of welded goods wagons and the improvement of the running; at the same time new types of wagons have been designed for fast trains.

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(1) Cf. Klein : « Vorrats- und Austauschbau bei Wagen » (Construction of wagons with interchangeable parts). Special number of the *V.D.I.*, 1925.

(2) Cf. Klein : « Die Einführung des Austauschbaues bei den Reichsbahnwagen » (Introduction of interchangeable designs in Reichsbahn rolling stock). Special number of *Glasers Annalen*, 1st July 1927.

a) Welded wagons.

Some caution is desirable when introducing new methods of building goods wagons as wagons, unlike locomotives and carriages, do not belong to any particular centre but are run as and where required; they frequently travel beyond their owning countries' frontiers. The first thing to be done is to make sure a wagon built on the new method can still be repaired in the usual way and cheaply in the Reichsbahn's shops. The technical conditions in neighbouring countries must also be kept in mind. The important factor, of course, is whether the new method is technically better or not. Welding has given such good results in other applications that a careful study had to be made into the advantages to be got by using it in wagon building. Welding definitely reduces the tare of the wagons, and consequently the dead weight of the trains. Welded wagons are less subject to corrosion than rivetted vehicles as the welded design is more open, with less hidden corners which are especially subject to rusting. Some classes of wagons, when welded, could be made to run better as the parts of the wagons are more rigidly assembled, an open wagon on a rigid welded frame being steadier than when on a rivetted one. Successful tests carried out in other fields showed that the cost of welded wagons would be less as soon as the staff had had sufficient experience and the design had been adapted to the requirements of welding practice.

Six (SS1, K, Om, V, R and G1) of the 11 classes of interchangable wagons are now being welded and 4 of these (K, V, R and Gl) have been made of St. 37 (*) and St 52 (**) steel in order to ascertain how much weight can be saved on the one hand by welding alone, and on the other by welding in conjunction with a lighter construction. Outwardly welding has made little difference in the appearance, as welding has not been allowed to interfere with the standardisation of types, which was so difficult to attain when designing the interchangeable wagons, nor with the principles on which the wagons are built. The only thing that had to be dropped was the interchangeability of parts, no longer necessary in the welded wagon. Mass production is still possible, especially when the details are designed to suit welding and standardised. Naturally this has not been done yet, purposely, so as not to interfere with this development in its early stage. As, however, a rather large number of goods wagons have already been welded, the general lines the standardisation of the details will follow are already clearly traced.

Figure 1 is the SS1 welded rail wagon with plate frame bogies. The stanchions and cross bearers are arranged differently from the riveted wagons; each stanchion is followed by a cross bearer so that each pair of stanchions forms, with the corresponding cross bearer, a gantry which absorbs the lateral pressure due to the load without the solebars being subjected to torsion to any extent.

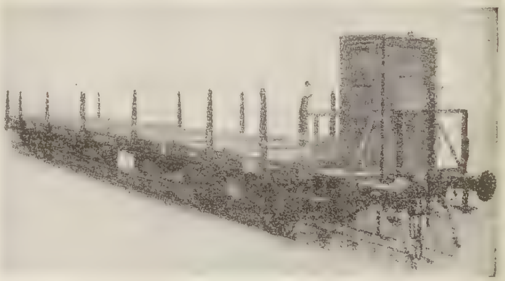

Fig. 1. — 8-wheeled (SS 1) welded rail wagons, built of St. 52 steel.

The brakesman's cabin and the railing round the platform are removable to allow of long loads being loaded over the headstocks. Access to the cabin has been

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(*) 23.5 Engl. tons per sq. inch.
(**) 33.0 Engl. tons per sq. inch.

improved by altering it so as to allow the brakesmen to stand upright in it without danger.

Figure 2 shows the welded lime wagon (K wagon) built of St. 52 steel. Standard rolled sections have been used as far as possible, but where this could not be done D.I.N. (Deutsche Industrie Normen) rolled sections were used. When there was no suitable D.I.N. section, chamfered plates were used; for example on the K wagon they were used for the body end stanchions, the door stiffeners, the bottom doors, and the roof.

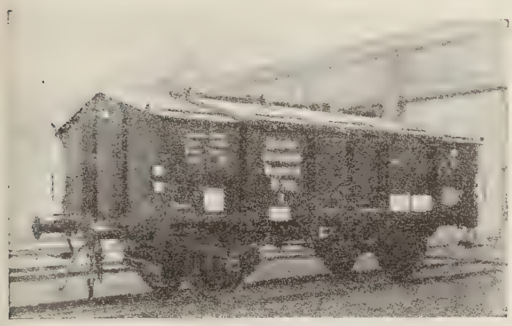
Fig. 2. — 15-ton welded lime wagon, built of St. 52 steel.

However, as chamfered sections or pressings are costly and cannot be used everywhere, in the welded Om wagon in St. 52 steel (fig. 3) new and readily rolled sections with which full advantage of the high tensile strength of the St. 52 steel can be taken, are used in the body end, the outside and middle longitudinals and the headstocks. In order to improve its running (see 2*b*), the wagon has been fitted with new spring gear, including 9-plate laminated springs, 1.50 m. (4′ 11 1/16″) long and of 120 mm. × 16 mm. (4 23/32″ × 5/8″) section, connected through shackles and rollers to the frame. The flexibility of the springs is about 12.5 mm. (0.49″) per ton.

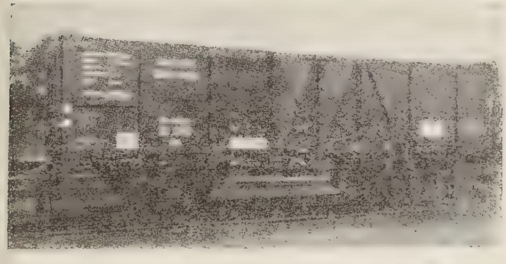
Fig. 3. — 20-ton (Om) open wagon with welded St. 52 steel frame and wood body

Welding has reduced the weight of the goods wagons, as delivered, by some 8.5 to 13 % with a maximum of 18 %. When St. 52 steel is used the reduction is from 18 to 23 %. These wide variations are due to the varying extent welding was used. This is shown very clearly in the SS1 wagon whereon the weight was reduced by 18 % because of the very large proportion that can be welded.

b) Improved running of goods wagons.

The present goods train speeds are as a rule 55 km. (34.2 miles) an hour for local trains, 60 km. (37.3 miles) for through trains and 65 km. (40.4 miles) for accelerated trains (both local and through). The different types of wagons are still quite satisfactory for these speeds.

Occasionally, however, these wagons are used to carry very urgent traffic and have to be attached to passenger trains the speed of which has been raised recently to 85 and 90 km. (52.8 and 56 miles) an hour. For such speeds new wagons had to be designed, and these wagons have been given the supplementary prefix S. Higher passenger train-speeds mean that the goods trains will have to give way to them more frequently and lose time. To meet this difficulty, the running qualities of the goods wagons have been improved so as to allow the speed of the local and through trains to be raised to 65 km. (40.4 miles), and that of the express goods trains to 75 km. (46.6 miles) an hour. In addition, steps are being taken to improve the running of the wagons with partitions (V) and the stanchion-sided wagons (R) so that they can run at 90 km. (56 miles) an hour.

For passenger train working, the covered wagons are the first to consider. As the G1 wagon with its 7-m. (22′ 11 5/8″) wheel base is the most suitable for development into a vehicle for fast trains, the Grunewald rolling stock testing station submitted such wagons to very full tests. It has been found that by increasing the wheel base to 7.70 m. (25′ 3″) and fitting new 9-plate laminated springs 180 m. (5′ 10 7/8″) long with 120 mm. × 16 mm. (4 23/32″ × 5/8′) section plates and 145 mm. (5 45/64″) long shackles, the altered wagons run steadily, whether loaded or empty, at 90 km. (56 miles) an hour.

A start was made by building 650 rivetted wagons which, except for the new running gear, slightly stronger spring gear, and longer wheelbase, were identical with the Gl. As they were intended for passenger-train service, they were fitted with steam-heating pipes and the passenger train brake (KKP), and at a later date, with 32-ton encased ring spring buffers. Owing to their large wheelbase, these Glhs rivetted wagons usually have to be moved several times when they have to be weighed, as about 80 % of the Reichsbahn's weighbridges are only 7.50 m. (24′ 7 1/4″) long; the result is a loss of time.

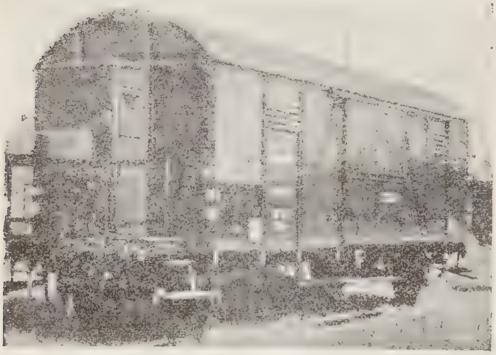

Fig. 4. — 15-ton (Glhs) welded St. 52 steel covered wagon for fast trains (90 km. = 56 miles an hour), with 7-m. (22′ 11.5/8″) wheel base.

Further tests were made to see if the old wheel base of 7 m. (22′ 11 5/8″) of the Gl wagons could be retained; good results were obtained by reducing the overhang at each end by 1 m. (3′ 3 3/8″). The resulting vehicle formed a new class, intermediate in size between the G and Gl wagons.

The wagons are welded (fig. 4). The floor area is 24.20 m² (260.4 sq. ft.). The running gear is the same as on the welded G.l.h.s. wagons, except that pressed steed axle guards 16 mm. (5/8″) thick, and high enough to be used for the Russian traffic were fitted. This wagon, also fitted with the K K P brake and 32-ton encased ring spring buffers, will probably be the goods wagon of the future.

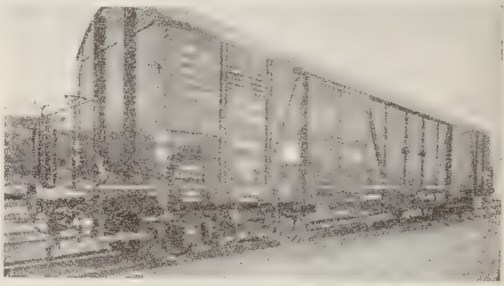

Fig. 5. — High-capacity welded covered wagon (GGhs) for fast trains.

For use on express trains running at speeds of 120 km. (75 miles) and over, 8-wheeled covered goods wagons have been built. These are the GGhs (fig. 5) wagons and are also welded. They have a floor area of 41.70 m² (448.8 sq. ft.) with a total length over buffers of 17.60 m. (57′ 9″). The weight empty is 22.5 t. (22.2 Engl. tons) and the load is 15 t. (14.8 Engl. tons). Two 2 m.

(6′ 6 3/4″) wide sliding doors are provided on each side to facilitate loading. Only 3 such wagons have been built so far, one with a steel roof, and it is not proposed at present to increase the number.

The experience obtained with the Glhs and GGhs goods wagons for fast trains has been applied to the other goods wagons. For example, the Glt (fig. 6) wagons have been fitted with the new running gear with 1.80 m. (5′ 10 7/8″) long springs. Owing to the softness of this spring (22 mm. = 0.87″ per ton deflection) which enables these wagons to run over rail joints without shock, the load has had to be reduced from 17.5 to 15.75 t. (17.2 to 15.5 Engl. tons), as in the Glhs wagons. There was no objection to doing this, as with the class of goods carried in the Glt wagons there is no advantage in having so wide a margin between the usual load and the maximum the wagon will carry.

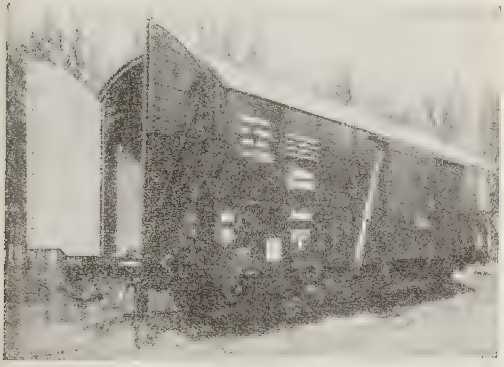

Fig. 6. — 15-ton end-door (Glt) high-capacity covered wagon-with 1.80 m. (5′ 10 7/8″) long springs.

The other 15-ton wagons, however, are often loaded up to capacity both for complete wagon loads and for parcels traffic. Any reduction in capacity would be a disadvantage as it would be necessary to take special care not to exceed the allowed load. For this reason the old load of 17.5 t. has been retained and these wagons are fitted with a 1.65-m. (5′ 5″) spring with a deflection of 17 mm. (11/16″) per ton. Figure 7 shows the R wagon with these springs. In the same way, the Om wagon which has a maximum axle load of 21 t. (20.7 Engl. tons) has been fitted with springs 1.50 m. (4′ 11″) long with a deflection of 12.5 mm. (0.49″) per ton. This means there are now three lengths of spring, 1.80 m. (5′ 10 7/8″), 1.65 m. (5′ 5″), and 1.50 m. (4′ 11″). All wagons fitted with these new springs have shackles and rollers. They are also fitted with 16 mm. (5/8″) thick pressed steel axle guards.

3. — Developments in special wagons.

Much progress has been made in welding large-capacity hopper wagons. A start was made by welding 2 large coke wagons, belonging to a class of rivetted wagons built of silicon steel (3). These were followed by 4 large-capacity all-welded coal wagons built of St. 52 steel, which had been adopted in the meantime. Improvements in the large rivetted hopper coal wagons had in course of

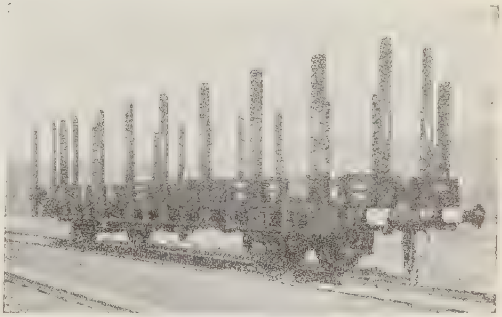

Fig. 7. — 15-ton flat wagon with wood stanchions (R) and 1.650-m. (5′ 5″) springs.

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(3) See CULEMEYER : « Fortschritte bei Grossgüterwagen » (Progress in large capacity wagon design), in *Verkehrstechnische Woche*, Nos 2, 3, 4 and 5, 1930.

time increased the weight to 21.4 t. (21.1 Engl. tons) and the original load of 60 t. (59 Engl. tons) had had to be reduced to 58.6 t. (57.7 Engl. tons). Thanks to welding, the dead weight was reduced to *less than* 20 t. (19.7 Engl. tons) so that it was possible to again bring the maximum load up to 60.73 t. (59.76 Engl. tons). In the case of the rivetted wagons, special precautions had to be taken where difficult to keep the doors tight under load and losses had to be prevented by using rubber jointing. Though this method was found to be effective and lasting, the packings cost a good deal to fit and the consumption of rubber pipes was considerable. The welded doors were consequently stiffened by chamfered rolled triangular sections applied to the inside of the doors. This made the special packings unnecessary. In addition, owing to the smooth surface of these stiffeners, there is no danger of the wagon contents sticking to them.

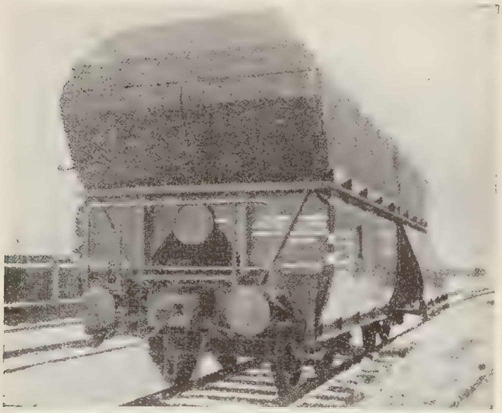


Fig. 8. — 60.73-ton all-welded St. 52 steel. 8-wheeled coal hopper wagon.

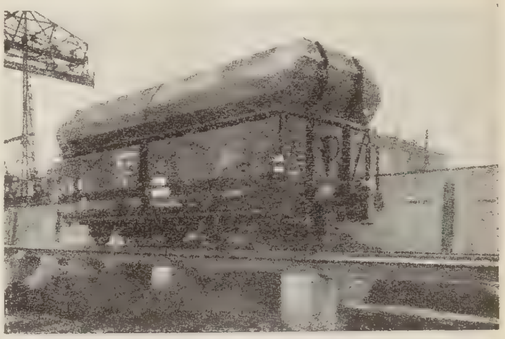


Fig. 9. — 56.3-ton 8-wheeled high-capacity St. 52 steel mixed (coal and sand) hopper wagon with welded bottom doors.

In recent years, two new types, a coal and sand wagon and a mineral wagon have been added to the classes of large-capacity wagons. The former is used for carrying coal from the Hohenzollern pit in Upper Silesia to the Odertal coke ovens at Deschowitz, whence they return loaded with sand for the washing plants. As shown by figure 7, their general appearance is like the ordinary large-capacity coal wagons but because sand tends to bank up rather than to slip, the hopper is given an angle of 55° at the top and 50° at the bottom. Owing to the steeper angle of the slope, the top of the hopper is placed higher up, and consequently, so as not to restrict the outlet, the doors also have had to be made deeper. All details and sheeting are made heavier than in the high-capacity hopper coal wagons, as the wagon is loaded by grabs of several tons capacity and is therefore subjected to rougher usage. The tare weight is 25.7 t. (25.3 Engl. tons), the maximum load 56.3 t. (55.4 Engl. tons), and the axle load 20 t. (19.7 Engl. tons). The triangular space between the hopper and the frame is closed in and can be heated in winter by portable heaters. For this purpose, a number of longitudinal openings have been cut in the lower casing plates, along the centre line of the wagons, over which the heaters are placed. The cold air enters through the central openings where it meets the heaters whilst the combustion gases pass down along the hopper face and escape through openings against the sole bars. The end plates are insulated by Zoste mattresses. By heating the wagons in this way, the wet sand which frequently is mixed with clay is prevented from freezing unless the temperature falls below — 10° C. (14° F.). These vehicles belong to the Upper Silesia wagon stock.

The high-capacity mineral hopper wagons (fig. 10) differ in many respects from the ordinary hopper wagons. The same running gear is used, but the body is hoppered; the whole contents can be dumped on either side to suit the receiving bins at the unloading points. Three cross partitions divide the body into four compartments, each with a side discharge door on both sides. There are therefore eight trap doors; these doors are held shut by camshafts which can be operated from each end of the wagon. Stepboards and handrails are fitted on both sides for the convenience of the staff when engaging the doors with the latches to close them. As part of the discharge plates can be tipped up, the springs and shackles are quite accessible. The tare of these wagons is 23 t. (22.6 Engl. tons) and the maximum load 57 t. (56.1 Engl. tons).

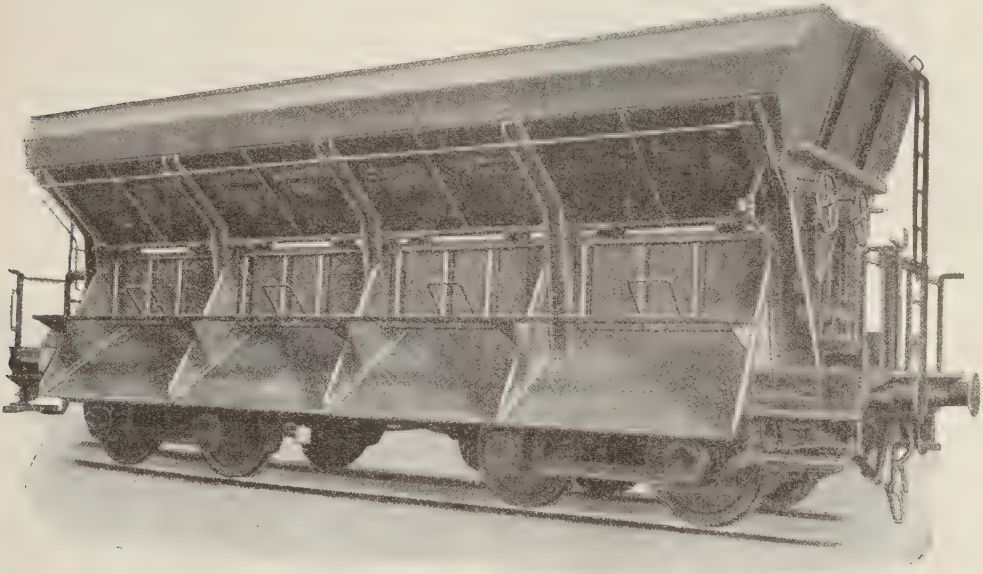


Fig. 10. — 57-ton 8-wheeled mineral hopper wagon.

The Reichsbahn decided, in 1933, to add to its stock some container wagons for carrying coal and coke from the Ruhr to Nordenham. These materials are for export and must not be spoilt by rubbing or breaking in transit, if they are to remain saleable. The best way of preventing this is to load them into containers which can be lifted off the wagons and lowered through the hatches into the ships' hold as this avoids all drop. The unloading cranes have a capacity of 15 tons. The dimensions of the containers correspond to this weight less their tare i. e. the coal containers have a capacity of 12.2 m³ (15.7 cu. yds.) and the coke containers 24 m³ (31.4 cu. yds.).

The dimensions have been made to suit the loading plant. To keep down the first cost the container flats have been designed to take either 3 coal or 2 coke containers. The tare weight is 12.9 t. (12.7 Engl. tons) and the maximum load 27 t. (26.6 Engl. tons). The total weight therefore is 40 t. (39.3 Engl. tons), which requires two pairs of wheels with a 20 t. (19.7 Engl. tons) axle load. 80-t. (78.6 Engl. tons) container flats could not be used as many of the collieries served are not equipped for loading such wagons. The solebars and headstocks are box girders assembled in such a way as to make any special shock-resisting cross members unnecessary. The top flanges of the solebars on which the containers rest are sloped towards the centre so that the components of the transverse forces set up tend to keep the containers shut. As the hollow box girders are strong enough to take any torsional forces, they can stand by themselves the pressure tending to keep the containers shut. The middle of the under frame and the brake gear are covered by deflecting plates which protect the draw gear and brake gear from any water dropping from the coal or coke. The containers simply rest on the underframe and are not specially held down in any way. Tests have shown that even under the most violent shocks in shunting, the bearing plates of the containers do not lift off their supports.

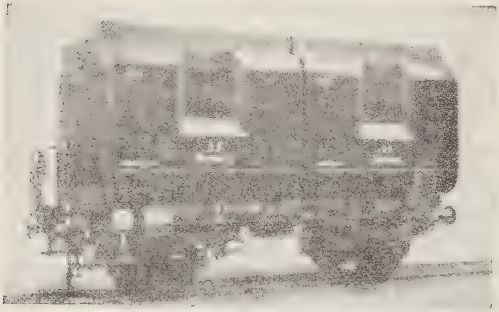


Fig. 11. — Welded St. 52 steel 4-wheeled coke wagon with 24 m^3 (31.4 cu. yards) containers.

The refrigerator wagons in turn have been much improved in design. By careful attention to details, by using a very efficient and light insulating material and by avoiding continuity in the metal parts, the weight of the rivetted refrigerator wagons fitted with the K K and hand brakes has been reduced to 14 tons and the heat loss has been reduced to between 0.35 and 0.4 kgr. cal./m^2/hour/°C. (2.27 tot 2.6 B.T.U. per sq. ft. per hour per deg. Fahr.). Particular attention has been given to obtain proper cooling air circulation. The two transverse ice tanks, as shown in figure 12, are surrounded by a double insulated casing which allows the cold air to leave the ice tanks at floor level and the warm air to circulate back to the tanks at the top under the roof. The doors are so located

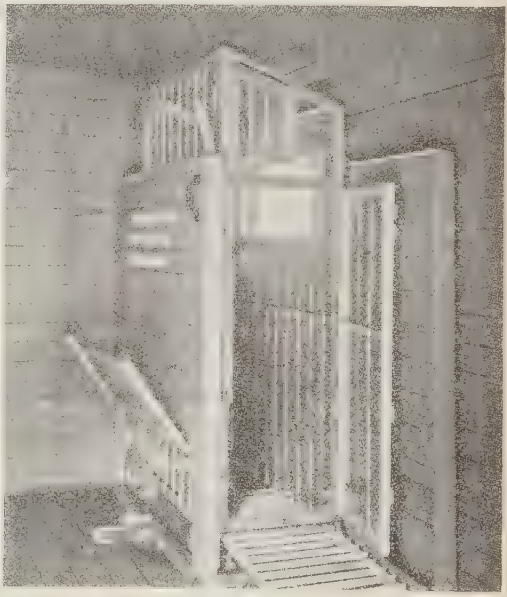


Fig. 12. — Ice tank with protecting casing and moveable gratings open.

that the ice tanks can be easily loaded and cleaned. For icing the wagons at intermediate points, hatches have been provided in the sides (see fig. 13). When foodstuffs which do not require ice cooling are being carried, the ice tanks and the casings protecting the wagon can be removed easily. Many foodstuffs, besides having to be kept cool, require thorough ventilation; ventilators which can be tightly closed are fitted in the roofs and sides. The fresh air is drawn over the ice tanks by aspirators fitted near the loading door, passes over the load from below upwards, and finally escapes through the opening in the middle of the roof. The hinged side doors are made airtight and are locked when shut.

Special wagons have been built for the through conveyance across Germany of animals suspected of being infected by contagious disease. They are fitted up in such a way that while no excrements are allowed to drop, the ventilation is not interfered with. Figure 14 shows a wagon for carrying large animals. The excrements are retained in a metal pan covering the whole floor, and are emptied through pipes located under the pan and leading to the ends of the wagon. These pipes are turned up the sides of the wagons so that no liquid can escape whilst running, and are turned down to empty the pan. Ventilating openings are made above the edge of the pans and are covered with deflecting plates somewhat in the form of louvres. The opening is covered by a double sliding door on the inside of the wagon through which air can circulate freely but through which neither rain nor excrement can pass. For this purpose the guiding plates in the door framing are roof-shaped. The outside sliding door cannot be shut until the inside one has been.

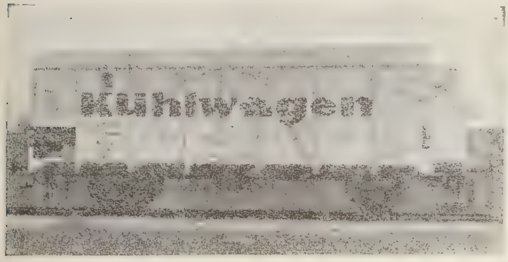


Fig. 13. — Refrigerator milk wagon with hand brake and K K power brake.

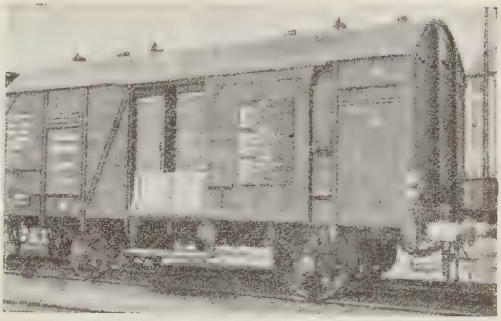


Fig. 14. — 15-ton covered wagon for carrying sick animals.

[621.13, 625. 2 & 669. 1]

Nickel steels in railway engineering,

by L. W. JOHNSON, M. Met.

(The Railway Gazette.)

Although wrought iron and, subsequently, carbon steel have in the past played their part in the realm of railway engineering, and are still doing so, the intense competition which this particular industry has had to face in recent years has necessitated the use of higher tensile alloy steels in order that better performance can be achieved. It may be of interest to discuss briefly the effect of nickel, and also various other alloying elements which are often associated with it, on the properties of steel.

Effects of nickel.

Mild steel is a ductile, tough material possessing a relatively low tensile strength. If it is necessary to increase its strength the simplest method is to add carbon, which is both cheap and efficacious. Certain drawbacks, however, arise from the addition of carbon, for, while the tensile strength or hardness is increased, there is a corresponding reduction in the ductility and toughness, so that in the higher carbon ranges it will be found that a moderately high tensile strength is associated with inferior toughness and, in certain cases, brittleness. It is in such circumstances that nickel is beneficial because when added to steel it simultaneously refines, strengthens, and toughens the iron or ferrite constituent, in which it is entirely dissolved. It will be found, therefore, that a nickel steel, compared with a corresponding carbon steel, will always be tougher for the same tensile strength, or, alternatively, for the same toughness will be found to be stronger. This difference is further accentuated by heat-treatment as will be seen from Table I, due to Brearly. Here is shown the effect of hardening and tempering two steels identical in chemical composition with the exception of the nickel content, so that they possessed the same tensile strength. The difference in the toughness is clearly demonstrated by the impact test figures obtained.

TABLE I. — **Mechanical properties of a nickel steel and a plain carbon steel heat-treated to give the same maximum stress.**

—	Carbon steel.	Nickel steel.
Chemical composition, per cent. :		
Carbon	0.33	0.33
Silicon	0.15	0.13
Manganese	0.63	0.63
Nickel	...	3.28
Mechanical properties, hardened and tempered :		
Yield point, tons per sq. in.	...	43.2
Maximum stress, tons per sq. in.	52.8	52.9
Elongation, per cent.	16.0	25.0
Reduction of area, p^{r} cent.	43.2	64.9
Izod impact, ft.-lb.	10, 11	100, 104

It is well known that in order to harden steel it is necessary to cool it at a rate which is greater than the rate at which transformation from one state to another takes place at the hardening

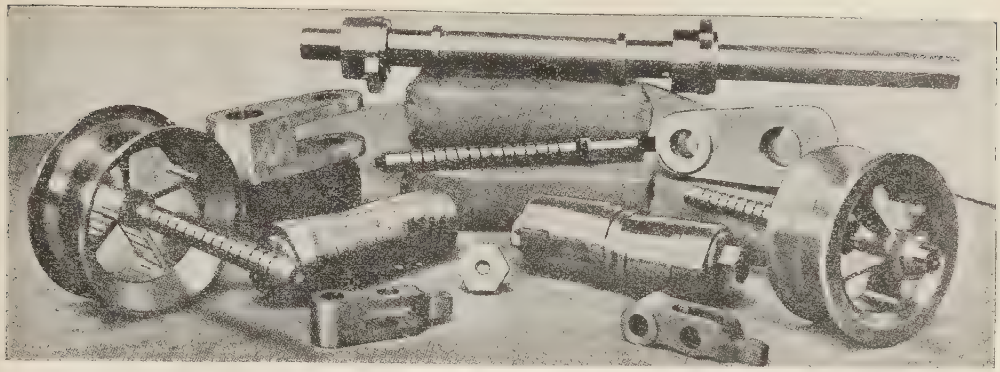


Fig. 1. — Steam and exhaust cams, levers and gears in the R. C. poppet valve equipment of the L. N. E. R. « Hunt » class locomotives are made of nickel-chromium case-hardening steel.

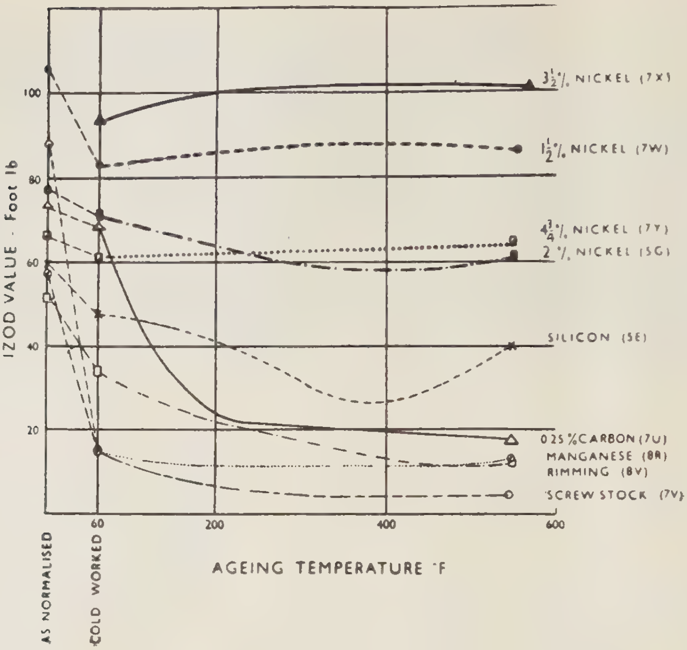
temperature. In the case of carbon steels, this transformation occurs very rapidly, and consequently drastic quenching has to be employed. This obviously favours the setting up of high internal stress, with the consequent danger of the formation of cracks and the production of distortion. Moreover it will also be clear that, owing to the relatively low thermal conductivity of steel, in the case of large sections the rate of cooling from the outside to the centre will progressively decrease, so that in the internal portions the beneficial effect of heat-treatment will not be realised. In actual practice in the case of ordinary carbon steels, the beneficial effect will be found to be produced right to the centre of bars only of about 1 1/8 in. diameter and less. This failure to obtain full quenching right through to the centre of large sections is known as « mass effect ».

Nickel, either alone or in association with other elements such as chromium or molybdenum, has been found beneficial in this respect, because nickel has the important advantage that it not only lowers the temperature at which transformation takes place, but also renders the rate of change much slower, so that a less drastic quenching medium, such as oil, can be substituted for water. By increasing the amounts of the alloying elements, the rate can be further slowed down so that hardening in air will be found sufficient. This means that besides eliminating « mass effect », the use of nickel also makes possible the elimination of cracking and distortion.

Nickel also has the capacity for restraining grain growth during heating, which, in the case of carbon steels, is sufficiently excessive to result in embrittlement of the steel. The restraining influence of nickel means that a wider latitude of quenching temperature can be allowed without the risk of a variation in properties, especially important in the case of large forgings, where it may be difficult to ensure an absolutely even temperature over the whole of a rather large furnace. The same effect is also of importance in connection with case-hardening steels, as the employment of a 3 % nickel steel enables the two water-quenches from 900° C. and 780° C., necessary for carbon steel, to be replaced by a single oil quench from 760° C.

Range of nickel steels.

Nickel, either alone or in conjunction with chromium and molybdenum, produces a range of steels which have an



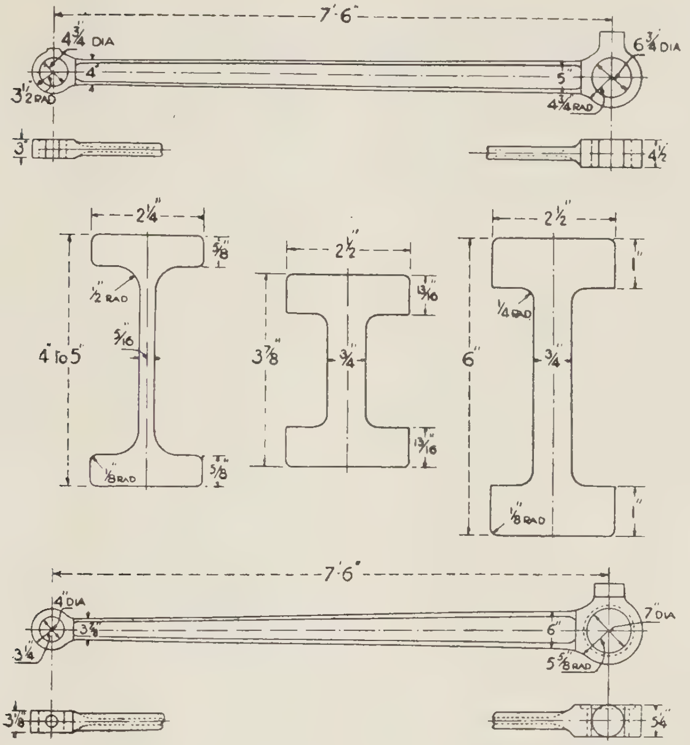
Composition of the steels tested.

Lot No.	Chemical composition, per cent.					—	
	C	Mn	Si	P	S	Ni	Al
7V	0.13	0.64	0.07	0.091	0.129	...	...
7U	0.25	0.38	0.11	0.010	0.031	...	...
8V	0 22	0.34	0.01	0.015	0.025	...	0.007
5E	0.27	0.62	0.20	0.027	0.040	...	0.009
8R	0.26	0.85	0.24	0.032	0.039	...	0.009
7W	0.16	0.44	0.22	0.010	0.029	1.44	0.009
5G	0.19	0.67	0.21	0.018	0.024	2.16	0.013
7X	0.15	0.52	0.26	...	. .	3 46	0.008
7Y	0.15	0.58	0.24	0.019	0.040	4.72	0.008

Fig. 2. — Effect of « ageing » on the impact values of carbon and nickel steels. Steels stretched 5 % at atmospheric temperatures and then reheated for one hour at specified temperatures. Note position of nickel steels at top of chart.

exceptionally wide application and will provide tensile strengths up to 120 tons per sq. in. and over, accompanied by good toughness and ductility. It will also provide case-hardening steels having core strengths as high as 90 tons per sq. in. again coupled with good toughness.

Whilst the 3 % nickel steel is the most extensively used of alloy steels, because of its excellent all-round properties, nickel in lower percentages is also bene-



—	Class « C » steel rod.	Alloy steel rod.
Piston load . . . . lb.	34 600	34 600
Unit stress, small end . . . lb. per sq. in.	6 000	8 460
Vertical stress. . . . . . » »	6 325	9 140
Horizontal stress . . . . . . » »	6 780	10 450
Inertia stress at wheel-diameter speed. lb. per sq. in.	9 950	9 650
Vertical stress at wheel-diameter speed. lb. per sq. in.	3 150	2 050
Combined inertia and vertical stress. lb. per sq. in.	13 100	11 700
Saving in weight over Class « C » steel rod, per cent.	...	30

Fig. 3. — Comparison of Class « C » and alloy steel rods, showing saving in weight effected by use of latter.

ficial for certain purposes. For instance the 0.4 % carbon steel, when used in either the normalised or hardened and tempered condition, has been found to give rather variable Izod values, and the addition of about 1 % of nickel was found to produce consistency, not only in the impact value, but also in the yield point. The addition of from 1/2 % to 1 % of nickel has also been found advantageous in a similar manner in the case of certain semi-alloy steels when they are used in large sections.

A further use of nickel has been discovered as a result of research in connection with copper constructional steels. The presence of copper, especially when greater than about 0.5 %, may result in surface cracking during hot working, but this can be prevented by the addition of small amounts of nickel (at least a half that of the copper content is recommended).

Boilers.

The present tendency towards the use of higher boiler pressures has caused the designer to look for other steels than the mild steel boiler plate, since it is not always possible to permit the extra weight which would be entailed if ordinary steel were used. For this reason the Canadian Pacific Railway adopted nickel steel boiler plate in 1926 in order to increase the boiler pressure by 25 % without any increase in weight. The factor of safety proved actually higher than before, and since then the use of such steel has extended to many other railways. The London Midland & Scottish Railway has built and is building a very large number of locomotives fitted with boilers in a nickel steel of which Table II gives particulars.

TABLE II. — **London Midland & Scottish Railway Specification for acid nickel-steel boiler plates.**

Chemical composition :	Per cent.	
Carbon	0.20 to 0.25	
Silicon	0.10 » 0.15	
Manganese	0.5 » 0.7	
Sulphur	0.04	
Phosphorus	0.04	
Nickel	1.75 to 2.0	
Mechanical properties :		
Maximum stress, tons per sq. in.	34 to 38	
Yield point, per cent. of M. S.	50	
Elongation, per cent.	22 to 24	
Reduction of area, per cent.	50	
Bend test : Bent 180° round a pin twice the thickness of the plate.		
Physical proporties obtained on cross-test of $^{11}/_{16}$ in. plate :	A	B
Yield point, tons per sq. in.	21.5	22.2
Maximum stress, tons per sq. in.	34.4	35.2
Elongation, per cent. on 8 in.	21.5	22.2
Reduction of area, per cent.	54.0	53.0

In Great Britain firebox plates are almost universally made of copper, but in localities where it is the practice to use steel, it is usual to keep the carbon content below 0.15 % and to fix a minimum nickel content of 2.0 %. The particulars given in Table III, for which the author is indebted to Colvilles Limited, indicate typical properties obtained from a steel containing 0.12 % carbon and 2.37 % nickel.

TABLE III. — **Properties of acid nickel-steel firebox plates.**

Specified physical properties :		
Maximum stress, tons per sq. in., min.	29	
Yield point, per cent. of M. S.	50	
Elongation, per cent. on 8 in., min.	20	
Reduction of area, per cent.	50	
Bend test : Bent 180° round a pin twice the thickness of the plate.		
Physical properties obtained :	$^3/_8$-in. plate.	$^1/_2$-in. plate.
Yield point, tons per sq. in.	20.3	18.4
Maximum stress, tons per sq. in.	30.3	30.0
Elongation, per cent. on 8 in.	27.0	30.0
Reduction of area, per cent.	59.5	61.4

The original choice of nickel steel for boilers was based not only on its increased tensile strength but also on the fact that an increase in nickel content in low carbon steels reduces ageing embrittlement as shown by the impact or slow bend tests on notched bars (see ageing diagram), reduces the grain size which can develop on recrystallisation, and raises the temperature at which grain markings of maximum intensity are observed in strain-etch tests (*).

TABLE IV. — **Typical tests of nickel-steel boiler plates.**

—	Great Western Railway.	Bengal-Nagpur Railway.
	Per cent.	Per cent.
Carbon	0.32	0.26
Silicon	0.078	...
Manganese	0.75	0.78
Sulphur	0.027	0.04
Phosphorus	0.028	0.03
Nickel	1.99	2.03
Normalised at 900° C. :		
Maximum stress, tons per sq. in. . . .	36.3 to 40.0	36.0 to 39.4
Elongation, per cent. on 8 in.	19 5 to 22.0	22 to 25

Both copper and Monel metal are largely employed for staybolts, but in cases where steel is favoured a nickel steel is also being used owing to its inherent toughness and ductility. Table V gives details of this particular type of steel, which incidentally is a good substitute for wrought iron in many applications.

It may be mentioned that this steel can be obtained in the form of hollow rolled bars, the centre hole being made by rolling with an austenitic steel core. This results in a very smooth, central round hole and thus reduces the chances of failure by fatigue formerly associated with the small imperfections found on the bore when sand or copper was used in the rolling operation.

TABLE V. — **Nickel steel for staybolts.**

Chemical composition :	Per cent.
Carbon, max.	0.05
Manganese	0.13 to 0.18
Sulphur, max.	0.04
Phosphorus, max.	0.02
Nickel, min.	2.0

—	Hot rolled.	Water quenched and tempered.
Minimum physical properties :		
Yield point, tons per sq. in.	15.5	20.0
Maximum stress, tons per sq. in.	21.5	26.0
Elongation, per cent. on 8 in.	30	22
Reduction of area, per cent.	65	68
Izod impact, ft.-lb.	...	90

In recent years there has been a distinct trend towards the use of alloy steels for reciprocating parts such as connecting and coupling rods, because the reduction in weight which can be achieved results in a reduction of the inertia stresses; furthermore the smaller balance weights required ensure a reduction in the hammer blow and the unsprung mass. The practice in this country has been to adopt nickel-chromium or nickel-chromium-molybdenum steel with a tensile strength varying from about 50 to 70 tons per sq. in. according to the particular requirements. Typical examples will be seen in Table VI.

The use of this type of steel makes possible a saving in weight of up to 35 % or more when compared with the standard Class C (**) carbon steel. The effect of this economy in decreasing the combined inertia and vertical stress

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(*) « Nickel Steels Resist Embrittlement », by H. J. FRENCH and C. M. SCHWITTER, *Iron Age*, July 14, 1932.

(**) Tensile strength, 32 to 38 tons per sq. in.

TABLE VI. — **Typical tests of locomotive connecting rods.**

—	London & North Eastern Ry.		Southern Ry.		Bengal-Nagpur Railway.
	Per cent.		Per cent.		Per cent.
Carbon	0.285		0.3 to 0.33		0.33
Manganese	0.65		0.6		0.52
Nickel	2.42		2.5		3.34
Chromium	0.62		0.6		0.68
Molybdenum	0.37		0.6		...
Heat-treatment.	London & North Eastern Ry. Oil quench and tempered.		Southern Ry. Oil quench and tempered.		O.Q. 850° C. temper 650° C. 2 hr. and O.Q.
	Specified.	Actual.	Specified.	Actual.	
Yield point, tons per sq. in.	40 min.	44.0	50 to 60	57.6	31.2
Max. stress, tons per sq. in.	80 »	54.0	60 » 70	65.0	52
Elongation, per cent.	18 »	22.5	17.5 min.	22	21
Reduction of area, per cent.	...	63.6	...	62	59.1
Izod impact, ft.-lb.	...	...	40 min.	62	...
Bend	180 deg. around 1 1/2 in. diam. bar	180 deg. sound	...	...	...

which can be obtained is well demonstrated by the illustration (*) which compares equivalent rods in Class C steel and 50 to 60-ton alloy steel.

In America tensile strength has been increased by adding nickel rather than by increasing the carbon, owing to the fact that the latter element lowers the toughness whereas with the former it is still retained or increased with a simultaneous increase in elastic properties. Large forgings are usually normalised to refine the structure and then tempered at a high temperature in order to remove internal stress. This type of steel is also successfully used in the heat-treated condition for such components as driving axles, the centre crank pin on three-cylinder locomotives, and piston rods. Table VII gives details of this steel.

TABLE VII

Chemical composition :	Per cent.	
Carbon	0.2 to 0.27	
Silicon	0.15 » 0.35	
Manganese	0.75 » 0.95	
Sulphur, max.	0.045	
Phosphorus, max.	0.045	
Nickel	2.5 to 3.0	
Typical test taken from centre of forgings :	Main rod 7 by 9 in. normalised and tempered.	Crank axle pin 10 1/2 in. diam., oil-quenched and tempered.
	Per cent.	Per cent.
Carbon	0.25	0.25
Manganese	0.84	0.88
Nickel	2.65	2.63
Yield point, tons per sq. in.	29.0	33.7
Maximum stress, tons per sq. in.	38.2	42.9
Elongation, per cent, on 2 in.	33.0	29.0
Reduction of area, per cent.	69.5	59.0

(*) Due to B. REED, « Alloy Steels in Locomotive Practice », *Mechanical World and Engineering Record,* June 12, 1931, p. 562.

Crank axles.

There still appears to be a difference of opinion as to the most satisfactory type of material for crank axles, steels varying in tensile strength from about 28 up to about 50 tons per sq. in. being used. In this connection it is of interest to note that in the days of the old Midland Railway it was found that a mild carbon steel having a tensile strength of at least 28 to 32 tons per sq. in., and a maximum carbon content of about 0.25 %, gave the longest life. In other words, in order to cope with the variable shock loading to which a crank axle is subjected, it was found advantageous to obtain as ductile and tough a material as possible, consistent with suitable strength. Assuming that in certain cases it may be necessary to increase the tensile strength of a steel for a crank axle, and taking the findings of the old Midland Railway as a basis, it will be obvious that the higher tensile steel must still be tough and, as we have seen previously, this can most readily be achieved by the addition of nickel. Actually certain Continental railways such as the Bulgarian and Rumanian State Railways and the Austrian Federal Railways, have adopted as standard 5 % nickel steel having a tensile strength of 38 to 40 tons per sq. in., and a minimum elongation of 18 % on 8 in. (*).

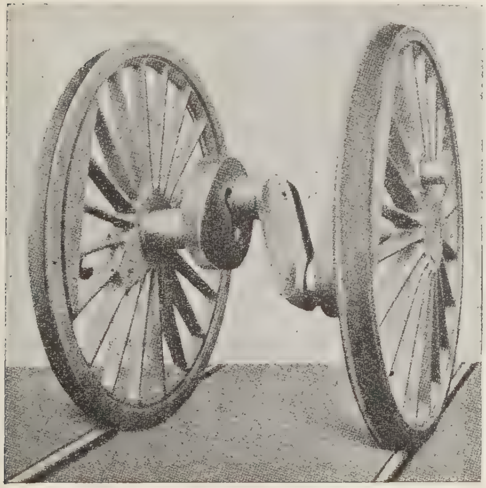

Fig. 4. — Locomotive driving wheels mounted on a 5 % nickel steel axle.

Frames.

In Great Britain, mild steel plate is the usual material of construction for locomotive frames, but in those cases where it is necessary to save weight, the 2 % nickel steel mentioned above for boilers will be found to be suitable.

In North America, where cast steel frames are more generally favoured, the Canadian Pacific Railway (**) some few years ago carried out a very careful investigation into the most suitable material for locomotive frame castings which would possess a moderate tensile strength, coupled with a high degree of ductility and toughness, especially at the low temperatures at which locomotives in Canada are occasionally operated. Their choice finally fell on to a 2 % nickel steel of which the following composition is typical :

	Per cent
Carbon . . .	0.14
Manganese .	0.69
Nickel . . .	2.0

and the average of 2 650 tests taken over four years showed the following properties :

	Per cent.
Yield point, tons per sq. in. . .	22.25
Maximum stress, tons per sq. in.	36.3
Elongation, per cent	30.3
Reduction of area, per cent. . .	61.2

(*) « Locomotive Crank Axles », by F. L. Baxter, *Engineer*, June 29, 1935, pp. 646-8. — See also *Bulletin of the Railway Congress*, February 1935, p. 257.

(**) « Selecting Alloy Steels for Locomotive Frames », by W. A. Newmann and C. F. Pascoe, *Iron Age*, January 14 and 18, 1932, pp. 172-5 and 284-300.

A series of Izod impact tests on pieces cut longitudinally, transversely, and vertically from the outside and centre of a test piece measuring 6 in. by 6 in. by 24 in. and cast integrally with the locomotive frame, averaged 60 ft.-lb. The heat-treatment given to the castings consisted of homogenising at 980° C. followed by normalising at 760° C., sometimes followed by tempering at 540° C. to 650° C.

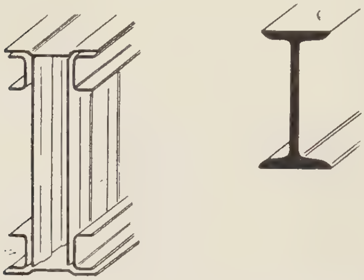

Fig. 5. — Beams drawn to scale with the same moment of inertia. Box girder (0.012 in. side webs and 0.05 in. chord strips) of welded 18/8 chromium-nickel stainless steel strip, weighs 38 % of 5-in. (10 lb. per ft.) structural steel I beam. Will carry 50 % greater bending moment when using factors of safety of 6 and 4 respectively, and has tensile strength 2 1/2 times as great.

Incidentally, it was pointed out by the authors that if any welding is to be done it is necessary to keep the manganese content well below 1.0 % in order to avoid any tendency to produce local hardening.

Corrosion-resisting and heat-resisting nickel-chromium steels are finding extensive application on locomotives for such parts as clothing belts, whistle components, fire-doors and deflector plates. While ordinary carbon steel castings are generally used for the locomotive drivers, mention may be made of a recent change by the Pennsylvania Railroad which, in order to reduce to a minimum any chances of spoke failure by shock or fatigue, is using both a 1 1/2 % nickel-molybdenum and 1 1/2 % nickel-vanadium steel. Either of these will give the following minimum properties :

Yield point, tons per sq. in.	24.5
Maximum stress, tons per sq. in.	38
Elongation, per cent	22
Reduction of area, per cent.	40

On actual test pieces taken from castings these properties were easily obtained and impact tests gave values of from 30 to 35 ft.-lb.

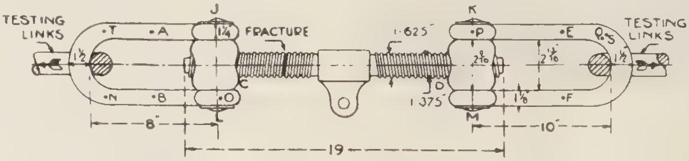

Fig. 6. — Results of test on Vibrac 2 1/2 % nickel-chromium-molybdenum steel link and pin coupling.

Rolling stock uses.

Couplings. — A 3 % nickel-chromium or nickel-chromium-molybdenum steel is often used for screw couplings, the tensile strength varying between 50 and 70 tons per sq. in., according to the particular requirements. The advantage of this type of material is two-fold : in the first place a lighter coupling, which greatly facilitates handling, can be used, and in the second place, owing to the

TABLE VIII

Position of gauge points.	Movement and set, in inches. Load in tons.											Max. stress.		Reduction of area, per cent, at bottom of thread.	Position and appearance of fracture.
	—	1	18	30	35	40	50	60	70	80	85	Tons.	Tons per sq. in. bottom of thread.		
AB = 4″	Closing in	zero	0.02	0.05	0.06	0.08	0.13	0.22	0.31	0.37	0.41	108.30	72.9	20.0	Broke in the screw Fracture : Silky fibrous.
	Set	...	...	...	none	0.02	0.08	0.17	0.25	0.31	0.35				
CD = 12″	Extension	zero	...	...	...	none	0.02	0.03	0.04	0.05	0.06				
	Set	...	...	...	...	...	...	...	...	...	none				
EF = 4″	Closing in	zero	0.02	0.05	0.06	0.09	0.17	0.25	0.31	0.39	0.41				
	Set	...	...	...	none	0.04	0.12	0.20	0.26	0.33	0.36				
JK = 15″	Opening out	zero	none	0.02	0.03	0.04	0 06	0.08	0.11	0.13	0.15				
	Set	...	...	...	...	...	...	...	none	0.02	0.04				
LM = 15″	Opening out	zero	...	...	none	0.02	0.04	0.06	0.08	0.10	0.10				
	Set	...	...	...	...	...	...	...	...	...	none				
NO = 8″	Extension	zero	...	...	...	none	0.02	0.04	0.07	0.09	0.12				
	Set	...	...	...	...	...	...	none	0.04	0.06	0.09				
PQ = 10′	Extension	zero	...	...	none	0.02	0.02	0.04	0.06	0.08	0.08				
	Set	...	...	...	...	...	none	0.02	0.04	0.06	0.06				
ST = 32″	Extension	zero	0 03	0.06	0.09	0.11	0.16	0.21	0.30	0.35	0.40				
	Set	...	...	...	...	...	none	0.03	0.10	0.14	0.20				

The above are the results of a pulling test applied to one screw coupling weighing 43 1/2 lb. Gauge points were marked on the coupling at AB, CD, EF, JK, LM, NO, PQ and ST, and the movement of these points was noted as the load was gradually increased. After certain loads had been applied the hydraulic pressure was released and any permanent set noted.

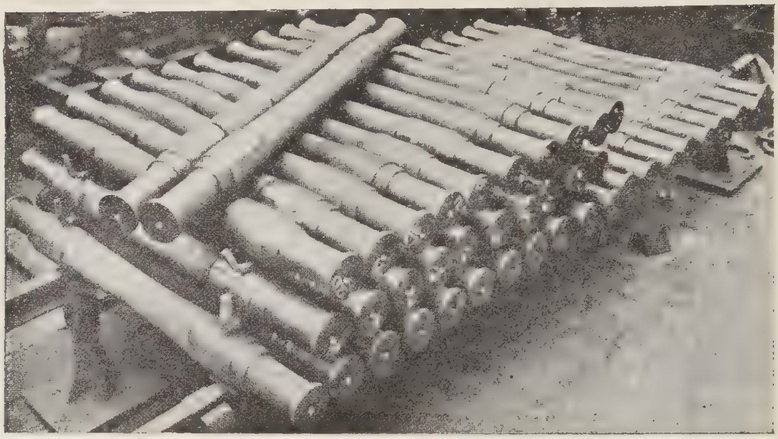

Fig. 7. — Railway axles in nickel-molybdenum steel.

high tensile strength, the threads do not distort and consequently jam, as has been found to happen when wrought iron or mild steel is employed. In Table VIII will be found particulars of a test carried out on a nickel-chromium-molybdenum steel screw coupling showing the movement and set when subjected to varying loads. The composition of the steel in question was as follows :

	Per cent.
Carbon	0.36
Silicon.	0.23
Manganese . . .	0.36
Sulphur	0.012
Phosphorus . . .	0.017
Nickel	3.5
Chromium . . .	0.67
Molybdenum . .	0.22

The steel was hardened and tempered to produce a maximum stress of 62 to 72 tons per sq. in., with an elongation per cent. on 2 in. of 20 to 15, and a yield ratio of 85 %. For those who prefer the knuckle type of coupling, a nickel-chromium steel casting is most suitable, since it provides, after a simple normalising operation, a moderately high tensile strength, together with good ductility. For example, the Chicago Steel Foundry Company has developed a steel known as Evansteel, of which the following composition is typical :

	Per cent
Carbon . . .	0.3 to 0.4
Nickel	1.0 to 1.5
Chromium . .	0.75 to 0.95

This is used for the knuckles of Pullman cars, and the following properties are obtained :

Yield point, tons per sq. in. . .	27 to 31
Maximum stress, tons per sq. in.. .	42 to 51
Elongation, per cent	24
Reduction of area, per cent . . .	35 to 45

In bending tests which were carried out on the actual components it was found that the nickel-chromium steel knuckle had a deflection of 0.68 in. at a load of 29.5 tons, whereas a carbon steel knuckle casting had a deflection of 0.7 in. at a load of 23 tons; the respective weights of the nickel-chromium and carbon steel castings were 25 and 29 lb.

Miscellaneous. — Whilst with modern fast trains very large saving in weight may not be desirable, owing to the better riding comfort which is obtained with heavier coaches, it is more than probable that in the near future, when very high speeds are the rule rather than the exception, greater attention may have to be paid to decreasing the weight of such trains. In this respect attention may be drawn to the very large saving in weight which can be effected by using corrosion-resisting nickel-chromium steel for the passenger coaches.

Such steels are also being increasingly used for various decorative features as well as for door handles and the like, since, owing to their excellent corrosion-resistance, it is necessary to clean only occasionally by using soap and water, thereby effecting considerable economies in upkeep.

Nickel alloy steel castings have not only been found to be beneficial in the case of the couplings mentioned above, but also in saving weight in the side frames and bolsters of bogies, the use of either nickel-manganese or nickel-chromium steels being favoured for this purpose. Mention may also be made of the beneficial effect which has been found by small additions of nickel of the order of 0.5 to 1.0 % to 1.0 % manganese steel castings, more consistent mechanical properties and better founding properties being secured.

Brief mention may also here be made of the excellent range of nickel alloy steels (*) which is available for such purposes as the design of transmission gearing of diesel engine cars.

The demand for increased performance.

Whilst the whole subject of railway engineering is obviously too extensive to cover adequately within the scope of one publication, it is hoped that sufficient examples have been given to show that nickel alloy steels, by their excellent range of physical properties, will still further enable railway engineers to overcome problems with which they may be faced in the future owing to the general demand for increased performance.

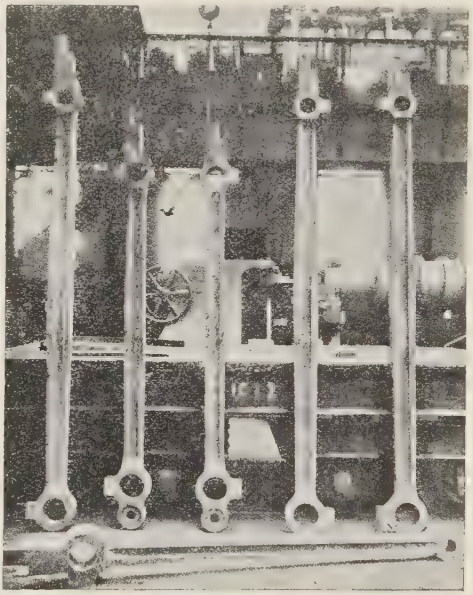

Fig. 8. — « Duratlas » nickel-chromium-molybdenum steel connecting rods after heat-treatment.

(*) These steels are referred to in publications AA2, AA4, and A11, issued free by the Bureau of Information on Nickel, Thames House, London. S.W.1.

[625. 143.4]

Long welded rails.

(*The Railway Gazette.*)

Eliminating the rail joint.

Rail joints are the bane of the permanent way engineer's life. He has to maintain them in such a condition as to minimise both rail wear and the manual work involved in avoiding dipped rail ends. The longer the rails that can be laid, the fewer the joints, and the less their initial cost and the expense of their upkeep. Experiments are therefore being made with the object of finding out the maximum length of rail it is practicable to use. Already it has been established to the satisfaction of many railway engineers that the longest rail which can conveniently be rolled may be safely used. So far this maximum length may be taken as 30 m. (98 ft. 5 in.), which is now a standard rail length rolled in Germany. Practically all main line relaying in that country is now done with 30-m. rails. In Belgium too the longest rails the mills can turn out are used, and these vary, according to the equipment of the mills, up to about 30 m. France is using 24-m. (78 ft. 9 in.) rails, and in Great Britain 90-ft. rails have been rolled and laid under exceptional conditions and experimentally. Beyond these lengths, end-to-end welding has to be adopted, and, in reconditioning main lines in Germany which do not require relaying, the former standard 15-m. rails are welded together to form 30-m. lengths. This practice was begun in 1927 on an extensive scale, after several years of experiment. When the suburban line connecting Berlin with Wannsee, 11 1/2 miles out, was electrified in 1933 it was relaid with 60-m. rails, two 30-m. lengths being joined end to end by the flash butt resistance method. Some years earlier, about 1929, experimental lengths of 60 m., 75 m., and 120 m. (393 ft. 8 in.) were welded up near Jungfernheide on the Hamburg line a few miles from the Lehrte terminus in Berlin. Longer continuously welded lengths of line are in existence in certain tunnels and on bridges in Germany, and elaborate expansion joints have been provided at their ends.

Most, if not all, of these welded lengths in Germany are of the latest standard type of Reichsbahn permanent way. The rails are flat-bottomed, weighing up to 49 kgr. per m. (98 lb. per yard), and are held in steel soleplates by means of bolts and nuts with spring washers, on the Geo system, the soleplates being fixed independently to wooden sleepers by four coach screws and to steel sleepers usually by welding. Between the foot of the rail and the soleplate there is a compressed poplar (or other hardwood) slip, the purpose of which is to soften the riding as well as to resist creep. In special cases rail anchors are used in addition, *e. g.*, on gradients exceeding 1 in 200, and where braking normally occurs. As a rule six anchors per 30-m. rail are used as a preventive of forward movement. The effect of these precautions is to hold the rails so firmly that no movement relative to the sleepers can occur. The permanent way in every case is well drained on a properly sloped formation and with ample broken stone ballast. The minimum depth of such in the middle of the track is about 12 in. below the bottom of the sleeper. The ballast shoulder extends to 2 ft. beyond the end of the sleeper and at that point is 2 ft. deep to the formation. Where clay is encountered a blanket of sand or ashes is laid between the clay and the stone ballast. The sleepers are mechanically tamped, and it is quite exceptional to find one not bearing firmly on its bed. In these conditions — and we emphasise the qualification — we understand that no trouble has been experienced, at any rate with lengths of rail up to 120 m. It will be observed that the conditions mentioned are practically ideal and extremely unfavourable to any tendency of the rails to buckle under a rise of temperature when they are not free to expand normally. An internal compressive stress is consequently set up in the rails, which then act as struts. Conversely, at low temperatures, when contraction cannot occur, there is a tensile stress. In the article hereafter we describe the M. & L. type of fastening used by the Delaware & Hudson Railroad of the U.S.A., which has now adopted the policy of eliminating rail joints so far as it is physically practicable to do so. The experience recorded with this type of fastening shows that, as in Germany, no relative movement occurs between the rails and the sleepers. We regard it as of prime importance that, in addition to such rigid fastenings, the condition of the road bed is such as to provide uniform and maximum support to the sleepers in order that lateral rigidity may be secured. Flat-bottomed rails have a greater lateral resistance to buckling, weight for weight, than bull-headed rails, and they are probably more adaptable to a firm fixing to the sleeper, although with the use of steel keys to hold the bull-headed rail to the cast iron chairs it has been found that creep can be virtually eliminated, thus indicating that a perfectly firm fixing may be obtained. The German extra precaution of using rail anchors as well may, however, be a wise one.

Confirmation that facilities for expansion need not be provided as a safeguard against buckling on well maintained and firmly fixed track is given by numerous experiences. There was for example the well-known 5-mile length of line of the Lehigh Valley Railroad laid about six years ago in moderate temperature with the rails touching, yet which gave no trouble through hot summers. The experience of the German Railways and the Delaware & Hudson has already been mentioned, and end-to-end welding has now been practised without any ill effect and on a considerable scale by the Victorian and the New South Wales Government Railways for the past five or six years. On both systems lengths of 225 ft. on straight and moderately curved lines are used, with decreasing lengths on curves sharper than 60 chains radius. Welding was first adopted on the electrified lines with heavy rails up to 110 lb. per yard, normally requiring bonding, but later long stretches through tunnels were undertaken, and by the end of last June, 39 track miles had been Thermit welded in New South Wales, and in Victoria about 63 miles. In most cases the welding has been done *in situ* or alongside the track by the Thermit process, but in Victoria 7 miles were welded into long lengths at the Melbourne depot and travelled considerable distances to the site. No trouble, however, was experienced in the transport of the long rails. The Thermit system of welding has so far been by far the most popular, but other methods have more recently been tried with good results. The fact that the transport of long rails has been shown to present no serious difficulties points to the extended use of electric flash butt welding for new rails. Where it is desired to weld up existing rails, and track possessions are difficult to arrange for the Thermit process, arc welding has been tried with a good deal of success. In Hungary for example a new type of arc welding has been used on a considerable scale, both on the local railways round Budapest and on the Royal Hungarian State Railways. Arc welding is also used successfully in South Africa and in South Australia. In Austria the Federal Railways have recently acquired a resistance welding plant for flash butt welding, and lengths of rail up to about 60 m. are, we understand, being laid in connection with extensions of electrification.

In this country experiments have been carried out by our main-line railways with lengths up to 420 yards of bull-headed track in the open, and even longer lengths on the London Underground lines in tunnel. In the former instance the keys were tightened up at 60° F. and no sign of movement at expansion gaps at each end have been observed during subsequent cold weather. The German practice is to lay long rails only in moderate temperatures. In very hot weather the work is suspended, nor is it carried out when the temperature is lower than about 40° F. At the latter temperature the gaps allowed are approximately 1/2 in. for 60 m. and 1/4 in. for 30-m. rails. It should be stated that all the long lengths of rail mentioned above are in running lines, though not always in those carrying the fastest traffic; and they have, of course, been in positions where normally a fairly long life is expected, and not where rails have to be changed frequently. Relative first costs of welded and mechanically jointed track vary according to circumstances, but there should be a considerable saving in maintenance of welded track, provided all the proper precautions referred to above are taken; and the advantage in smoother and quieter running should in time become tangible.

(Editorial, *The Railway Gazette.*)

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* *

An American railway to abolish rail joints. Precautions to ensure safety.

By the kindness of the President of the Delaware & Hudson Railroad, Mr. L. F. Loree, who has sent us a copy of a paper presented, on January 22, to the Maintenance of Way Club of Chicago by Mr. H. S. Clarke, Maintenance of Way Engineer, Delaware & Hudson Railroad, we are enabled to give an account of the current permanent way practice of that company. It may be recalled that in our issue of February 15, 1935, we recorded the fact that on the Delaware & Hudson certain experimental lengths of main line track had been welded into continuous lengths up to a maximum of 2 700 ft. at Albany during the summer of 1935, and at Mechanicville in the summer of 1934. So successful have these installations proved that the Delaware & Hudson Railroad has decided to eliminate rail joints altogether so far as is practicable, having regard to switches and crossings and track circuits. The latest installation, in which continuous rail lengths of as much as 6 970 ft. have been laid, is near Schenectady.

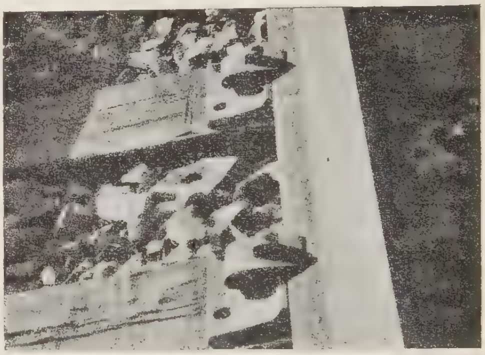


Fig. 1. — 131-lb. rail held to soleplates by M. & L. spring clip fastenings. Note independent fixing of soleplates to sleepers.

In his paper Mr. Clarke summarised the well-known disadvantages of rail joints, which, in North America where very heavy axle loads are the rule, are apt to be a source of greater expense in permanent way maintenance than in Great Britain. An idea of the importance of the rail joint has been given by the Committee on Economics of Railway Labour of the A.R.E.A., which in various studies estimated that about 45 per cent of the labour in track maintenance is devoted to keeping the rail joint in proper line and level.

Mr. Clarke regards a rail as like a gas, which, if allowed to remain at the same pressure, changes in volume in direct relation to changes in temperature. If, however, it is confined so that it cannot move or expand it increases its pressure with an increase in temperature. Similarly rails which are free to move may expand considerably in summer and contract in winter. If the rail, laid in moderate weather, is held fixed in position by outward forces such as adequate fastenings to the sleepers, ample ballast to provide sufficient frictional resistance to prevent the sleepers moving, and so on, it will subsequently be stressed internally, the metal being in tension in cold weather and in compression in hot weather, but the carrying capacity of the rail will not be modified.

On the Delaware & Hudson, M. & L. rail fastenings are used. To a double shouldered soleplate secured to the sleeper by screw spikes are bolted two spring clamps which bear on the base of the rail, pressing it down with great force, yet allowing a certain amount of flexibility necessary for the normal wave motion of the rail under the action of the rolling loads which it must support. The clamps, which replace the usual spike for holding the rail in place, exert a force of about 2 500 lb. each which tends to prevent creep. Since the rail-to-soleplate fastening is independent of the fastening of the latter to the sleeper, each group is free to perform only the work it is designed to do, while the rail, the soleplate, and the sleeper are incorporated into one strong but elastic and flexible unit. Both the vertical motion of the rail and of the sleeper are greatly decreased compared with the old method of fastening, and it has been found that this means a lessened pounding on the ballast structure beneath the sleeper and a consequent reduction in the amount of attention required in packing.

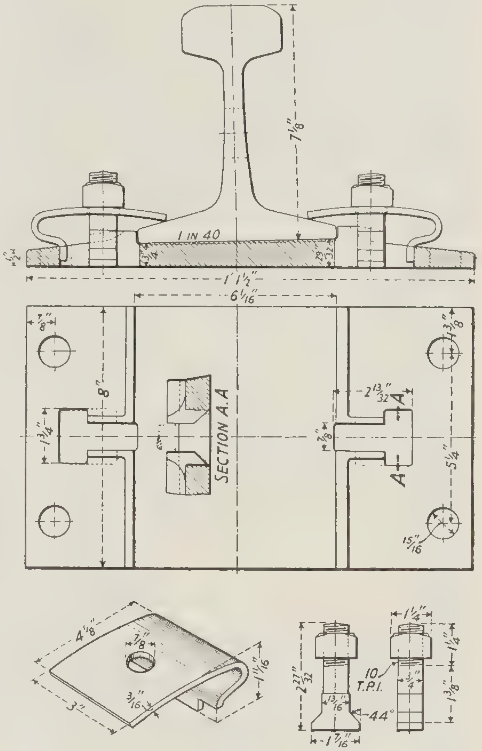


Fig. 2. — M. & L. type rail fastening details.

The original installations of M. & L. track were laid in winter with the standard expansion gaps at the joints. The following summer it was noted that this rail had not closed up, and in the succeeding year the expansion gap was halved. Still the rail did not close in hot weather, and after that the rail was laid tight. In Mr. Clarke's experience, where rail is so fixed, as in M. & L. construction, that it cannot expand into an ex-

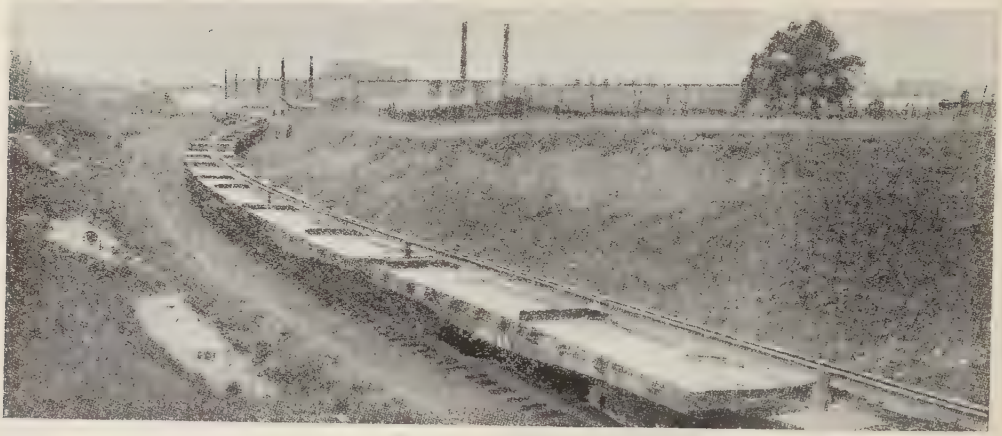


Fig. 3. — 131-lb. rails welded into 1 400-ft. lengths in transit to site of relaying.

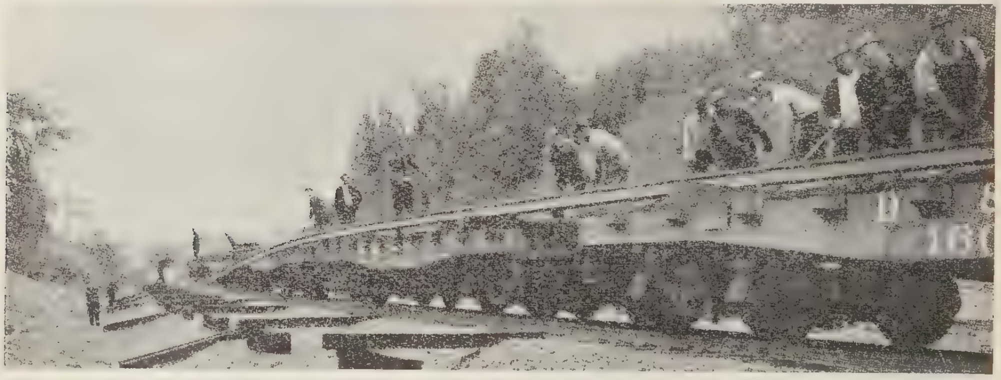


Fig. 4. — Unloading the long welded lengths at site.

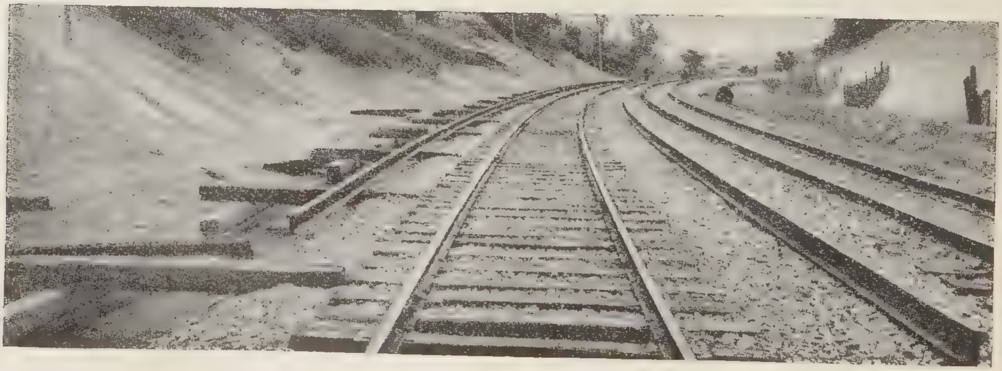


Fig. 5. — Long welded rails ready to be laid.

tended position when heated and cannot move in any other way, as, for instance, by buckling, it must remain unaltered in size, since the external force holding it is greater than the compressive stress set up by the temperature rise. Alternatively, it the rail cools below the temperature at which it is fixed, a tensile stress is created to be resisted by the influence which fixed the rail.

If the tendency of track to buckle under rises of temperature with long rails is still regarded as a danger, Mr. Clarke points out that the difficulty can be entirely eliminated either by allowing the track to take its set in its expanded position in the extreme hot periods, or by welding the track in hot weather. Thereafter the only inherent stress will be a tensile stress which will be greater in the cold months, but as it is far below the elastic limit of the rail steel it will not be sufficient to affect the service strength of the rail.

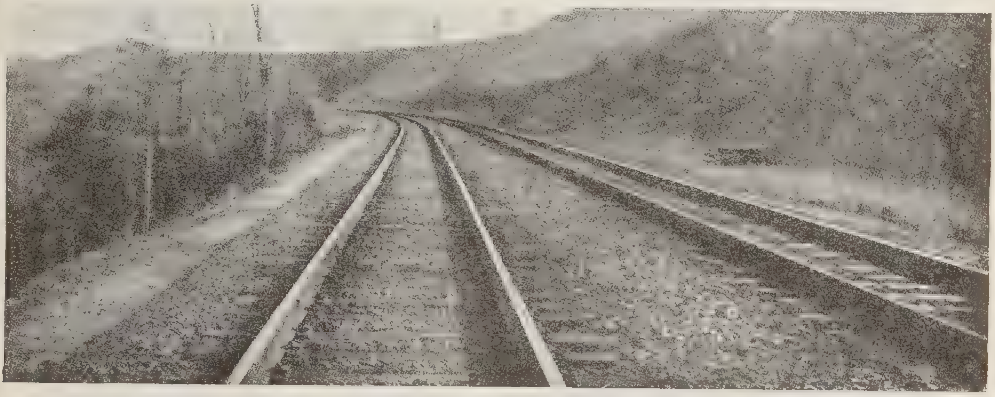


Fig. 6. — Finished jointless track on the Delaware & Hudson Railroad.

The method of welding so far mostly used on the Delaware & Hudson Railroad is the Thermit pressure type. This is a fusion weld on the base and about halfway up the web, the rest of the web and the head being a pressure weld. To effect this combination weld, the base and web of the rails to be joined are cut back 1/4 in. with an oxy-acetylene torch to a distance of 1 1/2 in. from the underside of the railhead in order to provide ample space for the entrance and fusion of the Thermit metal with the rail metal. The ends of the rails are also cut on a bevel from the top backward into the rail a distance of 1/32 in. at the base. When the rails are set up for welding, therefore the heads are in tight contact and a gap of 1/2 in. is provided between the adjacent webs and bases.

The rails are first clamped together with the ends slightly raised to obtain proper line and surface. They are then pre-heated with petrol burners, and when a temperature of from 1 700° to 1 800° F. is reached the Thermit, which consists of iron oxide, aluminium and slag, is ignited. In about 20 seconds, a temperature of 5 000° to 5 500° F. being reached, the molten metal is poured into a mould which has been clamped round the rail ends prior to the pre-heating. The metal is sufficient to fill the mould to about halfway up the web, and the slag which results from the reaction fills the remainder of the mould over the top of the rail.

The metal round the base and web

melts the rail so that the whole becomes a molten mass. The slag round the head of the rail and the upper part of the web raises it to a welding temperature of about 2 100° F. in about three minutes, when the ends are pulled together approximately 1/4 in. by drawing up the heavy clamps, thus producing the high pressure necessary to perfect the butt weld. After the two types of welds have been made simultaneously the joint is stripped of its mould and ground to bring the head of the rail, at the point which has been upset by the pressure weld, to the line and surface of the adjacent rail.

In his paper Mr. Clarke mentioned that his company had also used to a small extent electric flash welding (this process was described in *The Railway Gazette* of April 28, 1933). Briefly, this method depends on continuous arcing between the rail ends. The two ends of the rails are fixed in the welding machine by clamps connected to the terminals of a low voltage transformer. One of the clamps is movable, and the faces are brought sufficiently close to form an arc, which, about two minutes after starting, produces heat sufficient for welding. The faces are then brought together under a heavy pressure which squeezes out all the metal that is molten and the weld is made. This method, unlike Thermit welding, is not practicable in the track, and in the Delaware & Hudson experiment 39-ft. rails were welded in lengths of three at the General Electric Company's works at Schenectady and transported to the track where they were further joined into long lengths with Thermit welds. The most remarkable installations to date of long welded rails on the Delaware & Hudson consist of four continuous rail lengths, two 6 970 ft. long and two 4 435 ft. long. They were welded together into 20-rail lengths on flat cars three miles from the site of their installation to which they were transported on the cars. The rails were of the 131-lb. standard section and were prepared at the rail mill ready for the welding process, the rail heads together with the upper 1 1/2 in. of the webs being machine-faced to assure clean true surfaces for joining and to avoid the necessity for carrying out this operation by and on the site. The normal fishbolt holes were replaced by a single hole 13 1/2 in. from each end of the rail, which was used as an anchorage for the clamps necessary to produce the welding pressure.

Two strings of rails, blocked up on sleepers and about 2 ft. from the sides, were mounted on the cars. The joints were made from one end, two welds being in progress at the same time, one in each of the strings of rails. An average of 20 welds a day was made when the work was in full progress, with two men making the sand moulds; one part-time man with an oxy-acetylene torch undercutting the rail ends below the head for the fusion portion of the welds; one man cleaning the rail ends; two men aligning the rail, adjusting the sleepers at the joints, and fixing the clamps; two men placing the moulds; two men making the welds, including the operations of preheating, pouring, stripping and moving their equipment forward; and two men rough grinding the rail head at the welds.

After welding, the rails were barred over to the centre of the cars about 3 in. to 4 in. apart so as to be subjected to the minimum movement in transportation round curves. End stakes were provided at about every third car to keep the rails in position, but otherwise no sort of fastening was made, nor had experience in transporting the rails even through curves of about 500 ft. indicated the necessity for any fastening since there was practically no movement of the rails on the cars.

On arrival at the site, the rails were

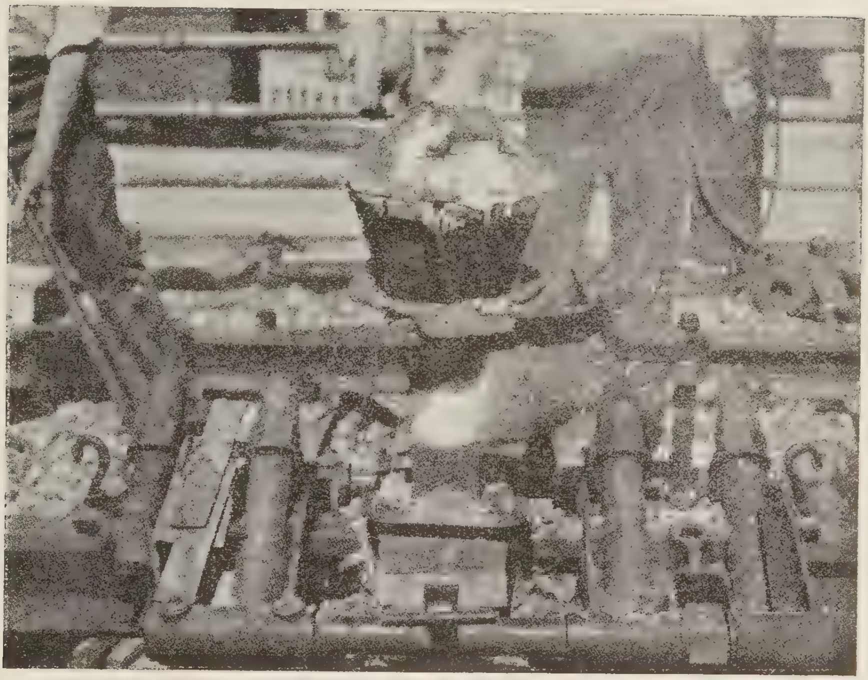


Fig. 7. — Thermit welding process in operation.

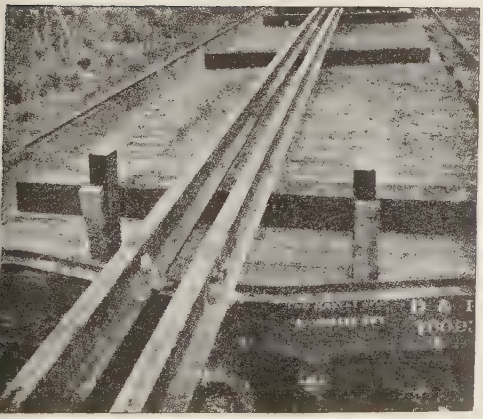


Fig. 8. — Welded rails loaded on trucks ready for transit.

Fig. 9.
Electric flash weld.

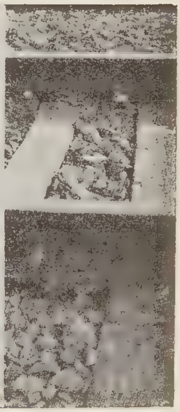


Fig. 10. — Thermit pressure weld.

barred off opposite sides of the cars by a gang of 14 or 15 men who accomplished the task in from 10 to 15 minutes without difficulty. To prevent the ends of the long rail lengths whipping off the cars they were held to the nearest running rail by loops of chain of sufficient length to restrict the lateral throw of the welded rail to the distance desired from the running rail. An alternative method of lifting the end of the rail off the cars was to use a ditcher derrick.

The rails, as will be seen from one of the illustrations, were unloaded in such a way that they could be easily barred over to position in the track. The joints in the track at the ends of the long lengths of rail were Thermit welded.

The experience gained from this trial installation demonstrates the advantages of welding into long lengths prior to laying the rails in the track, and opens up the way to the use of the electric flash method of welding. When Thermit welding is performed *in situ* possession of the track has, of course, to be obtained, which, according to the density of the traffic, increases the time and therefore the cost of carrying out the work. In the earlier installations already mentioned at Albany and Mechanicville, the rails were welded alongside the track, but often this method is less speedy and convenient than the method just described of welding the rails on the cars themselves.

Mr. Clarke stated in his paper that if the welds are properly made they give as good service as the unwelded part of the track, but in any case he did not feel particularly concerned about the safety of the welds because, even in the event of a fracture, the M. & L. type of fastening would prevent the rail from getting out of alignment. If breaks occur, either at joints or elsewhere due to rail defects, fresh plates will be applied temporarily and the breaks welded up later, a short section of rail being added for the closure welds. Transverse fissures, said Mr. Clarke, did not present any greater difficulty in continuous rail than in the present track construction, as by keeping the heat members together any heat can be removed without difficulty. The use of the Sperry detector car, coupled with the controlled cooling of the rails, has greatly minimised this danger.

The rails which are being welded are of molybdenum alloy, two types of which are being tried, each with 0.35-0.40 molybdenum and 0.04 maximum phosphorus, and one having 0.54-0.67 carbon, 1.20-1.50 manganese, and 0.10-0.15 silicon; the other has 0.67-0.80 carbon, 0.60-0.90 manganese, and 0.15-0.25 silicon. The physical requirements for molybdenum rail are the same as for other rail, although, in several cases, it was found necessary to modify the drop test to a 15-ft. drop. The rails are not heat treated, but those laid subsequently to 1934 have been subjected to controlled cooling.

There has been no perceptible movement of the long rails in the Delaware & Hudson installations, and indeed no indication of any movement has been detected between the clips and the rail throughout the entire stretch of the various installations; neither has there been any indication of movement in the joints at the ends of these stretches other than what would be normal in a 60-ft. rail.

An account of the research work which is now being undertaken in connection with welding was given by Mr. Clarke at the conclusion of his paper. The various types of welds, he said, are being subjected to all the usual tests performed upon rail steel, including drop tests, tensile tests, bend tests, notch tests, and metallographic examinations. Perhaps the most important tests are those which are being made on a special machine which subjects the weld to a rolling wheel load, thus duplicating actual service conditions as closely as possible. With this machine years of service in the track can be duplicated in a few weeks. It is probable that the A.R.E.A. Committee on Stresses in Track, which has had the Delaware & Hudson installations under close observation, should be able to furnish some interesting data at the March convention of the A.R.E.A.

Two other railways in the U.S.A. are reported by the Metal and Thermit Corporation of New York to be installing experimental lengths of long welded rails. One is the Bessemer & Lake Erie, which uses the Geo type of rail fastening, now standard on the German State Railways, and the other the Southern, with ordinary double-shoulder soleplates.

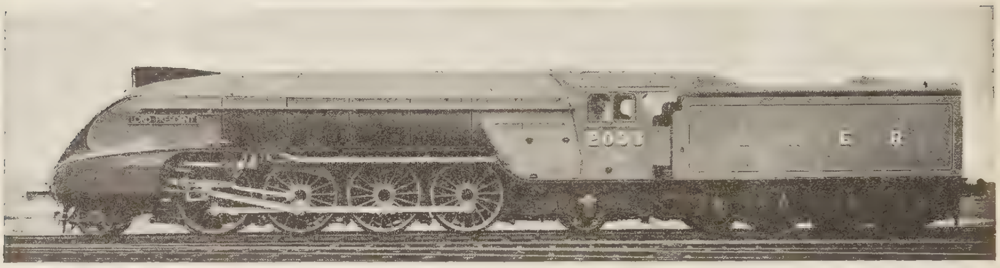
RECENT DEVELOPMENTS.

IN RAILWAY PRACTICE.

[621. 132.3 (.42)]

2-8-2 type three-cylinder engines,

London and North Eastern Railway.



As a development of the two 2-8-2 type passenger locomotives, No. 2001, « Cock o' the North » (1), and No. 2002, « Earl Marischal » (2), which were put into service on the Scottish lines of the London & North Eastern Railway in 1934, a further series of four similar engines are now being completed at the Doncaster Works, to the designs of Sir Nigel Gresley, C. B. E., D .Sc., the Chief Mechanical Engineer of the Company, to whom we are indebted for the particulars hereafter.

The first of these locomotives is numbered 2003, and has been named « Lord President ».

The front end has been designed on similar lines to that of the « Silver Link » type engines (3), as this external form has been found entirely successful in lifting the smoke clear of the engineman's view.

The boilers of the first three engines will be identical with that on the previous 2-8-2 type engines, but the boiler of the fourth will be somewhat altered in its proportions, having a longer combustion chamber, giving a firebox heating surface of 253 square feet, and a firebox volume of 319 cu. feet. The firegrate has an area of 50 sq. feet and is fitted with narrow firebars giving 56 % air space.

A 43-element « Robinson » superheater is fitted, the elements extending to within 9 inches of the copper tubeplate.

The three cylinders are 21 in. diameter × 26 in. stroke, and are cast in one piece, all three cylinders driving the second pair of coupled wheels.

The piston rods and heads are of Class « C » steel forged in one unit.

The piston valves are 9 inches in diameter and are fitted with narrow rings.

The valves of the outside cylinders are operated by Walschaerts gear, whilst the inside valve is actuated through a system of two to one and equal levers from the outside valve spindles. The whole of the valve gear is fitted with ball and roller bearings.

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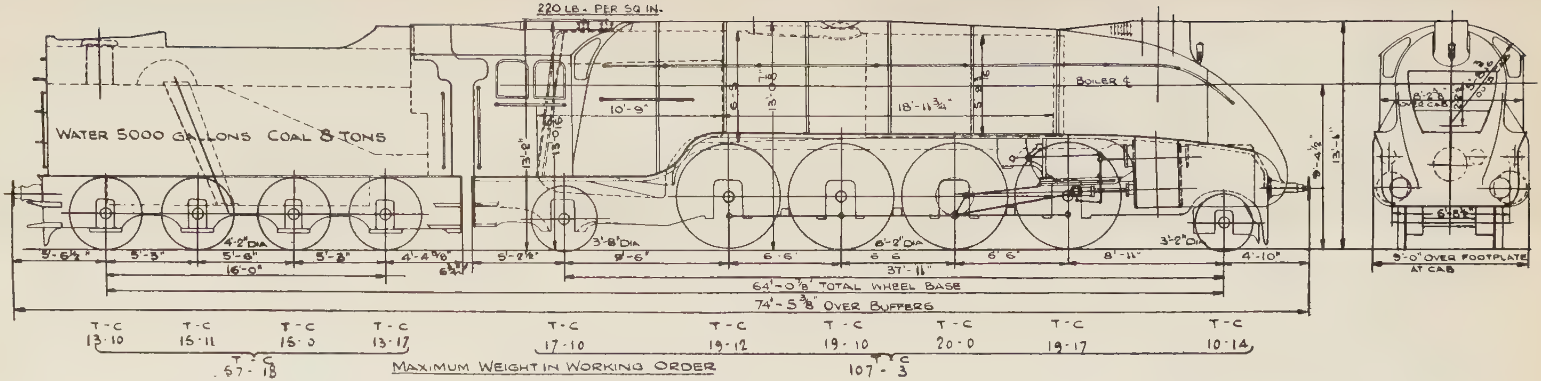
(1) See *Bulletin of the Railway Congress*, June 1934, p. 626 and November 1934, p. 1218.

(2) See *Bulletin of the Railway Congress*, January 1935, p. 129.

(3) See *Bulletin of the Railway Congress*, November 1935, p. 1299.



Leading dimensions and ratios.

Grate:

Length on slope	7' 2"
Width	6' 11 3/4"
Grate area	50 sq. ft.

Firebox:

Height of crown above foundation ring — front	6' 8 13/16"
Height of crown above foundation ring — back	6' 0 5/16"
Interior length at top	9' 2 3/4"
Interior width at boiler centre	5' 4 1/2"
Thickness of copper plates — sides and back	9/16"
Thickness of copper plates — tubeplate	9/16" and 1 1/4"

Boiler:

Outside length of firebox, overall	10' 9"
Outside length of firebox at bottom	7' 11 1/4"
Outside width of firebox at bottom	7' 9"
Maximum diam. of barrel	6' 5"
Thickness of barrel plates	23/32" and 25/32"
Thickness of wrapper plates	9/16"

Tubes, small:

Material	Steel
Number	121
Diameter outside	2 1/4"
Thickness	10 I. W. G.

Tubes, superheater flues:

Number	43
Diameter outside	5 1/4"
Thickness	5/32"
Length between tubeplates	18' 11 3/4"

Heating surface:

Firebox	237 sq. ft.
Tubes, 2 1/4"	1354.2 sq. ft.
Flues	1122.8 sq. ft.
Total evaporative	2714 sq. ft.

Superheater:

Number of elements	43
Diameter inside	1.244"
Heating surface	776.5 sq. ft.
Total heating surface	3490.5 sq. ft.
Two Ross pop safety valves	3 1/2" diam.
Working pressure	220 lb./sq.

Axles:

	Dia.	Len.
Journals, pony	6 1/2"	9"
Journals, coupled	9 1/2"	11"
Journals, trailing	6"	11"

Crank pins:

Outside	6 3/4" × 6"
Inside	9 1/4" × 6"

Coupling pins:

Leading	4 3/4" × 4"
Driving	7 1/2" × 4 1/2"
Intermediate	4 3/4" × 5"
Trailing	4 3/4" × 5"

Springs — Pony: Helical, 10 3/16" long free, 5 1/2" outs diam., Timmis section. Coupled wheels: Laminated 3' 6" crs, 15 plates 5" wide × 1/2" thick. Trailing wheels: Laminated 4' 6" crs, 14 plates, 5" wide × 5/8" thick.

Cylinders:

Number	3
Diameter	28"
Stroke	26"

Motion:

Type: Outside	Walschaerts
Type: Inside	Gresley
Type: Valves	Piston
Diam. of valves	9"
Max. travel of valves	5 5/8"
Steam lap, ins. cylinders	1 5/8"
Steam lap, outs. cylinders	1 9/16"
Exhaust lap	Nil
Cut-off in full gear	65 %

Tractive effort at 85 % boiler pressure	43 462 lb.
Total adhesive weight	176 848 lb.
Adhesive weight / Tractive effort	4.06
Brakes	Vacuum

A double blast and chimney is fitted in conjunction with « Kylchap » cowls.

Access to the main smokebox door is obtained through doors in the front streamlined case, one of which lifts upwards and the other drops downwards over the buffers. The doors are hand-operated through bevel gearing. A chime whistle is fitted in front of the chimmey.

The coupling and connecting rods are of nickel-chrome steel.

The leading pony truck is of the double swing-link type with a translation of 5 1/2 in. each side of the centre line.

The trailing carrying axle is fitted with « Cartazzi » axleboxes giving a side translation of 3 in. either side of the central position.

Vacuum brake is fitted to both the engine and tender; there being four 21 in. diameter brake cylinders on the engine, and two 21 in. diameter cylinders on the tender.

The boiler is fed by a Davies & Metcalfe No. 12 Class H exhaust steam injector on the right hand side, and by a Gresham & Craven No. 11 under footplate injector on the left hand side.

The boiler and firebox are insulated with « Alfol » foil made up into the form of mattresses.

The eight-wheeled tender carries 5 000 gallons of water and 8 tons of coal.

The weight of the engine and tender in working order is 165 tons 1 cwt.

MISCELLANEOUS INFORMATION.

[621. 33 (.439)]

1. — Electrified lines in Hungary,

by E. LAJTHAY,

Chief of Electrification, Hungarian State Railways.

(*Electric Railway Traction*, Supplement to *The Railway Gazette.*)

The earlier electrified lines of the Hungarian State Railways have become overshadowed in recent years by the Kando main-line electrification from Budapest to the Austrian frontier at Hegyeshalom (*), but the technical and operating features of the lines are of interest. The pre-war electrifications are in the Budapest district and comprise a 60-mile system

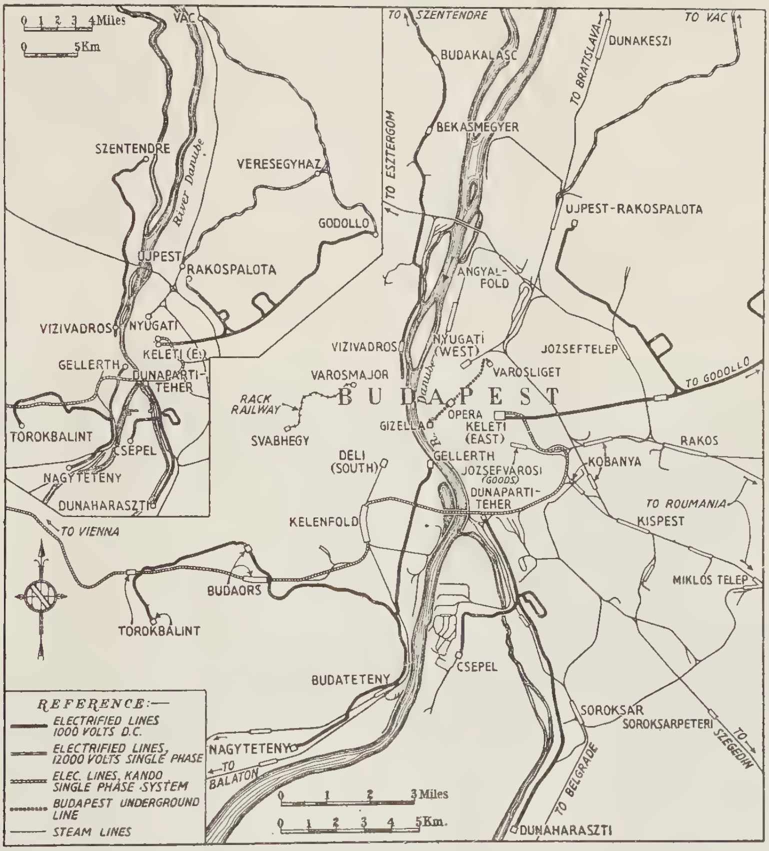


Fig. 1. — Map of the railways in the vicinity of Budapest showing the various electrified suburban and main lines, all of which, except the Budapest Underground, belong to the Hungarian State Railways.

(*) *The Railway Gazette*, July 7, 1933. — See also *Bulletin of the Railway Congress*, August 1933, p. 753.

on the 1 000-volt D.C. principle and two lines aggregating 32 miles of the 12 000-volt single-phase type.

The Budapest local railways connect the city with the populous surrounding country. The route mileage is split up a follows between four different lines :

	Length of line.	
Budapest-Godollo; Rakospalota-Godollo . . .	38.0 km.	*(23.6 miles).*
Budapest-Dunaharaszti; Budapest-Csepel . .	16.5 »	*(10.3 miles).*
Budapest-Szentendre	20.0 »	*(12.4 miles).*
Budapest-Nagyteteny; Budapest-Torokbalint .	25.0 »	*(15.5 miles).*
Total . . .	99.5 km.	*(61.8 miles).*

Of these, 94.5 km. (58.7 miles) are double and 5 km. (3.1 miles) single line, and there are several smaller single line branches in addition. All are of standard gauge. Electric operation on the 1 000-volt direct current system was inaugurated in the year 1911. Some tracks, common with the Budapest tramways, are worked at 600 volts D.C. Tracks common with the tramways include those from the Danube Quay (Duna to Csepel) and from Gellerth to Torokbalint, and from Rakospalota to the junction with the Budapest (Est)-Godollo line.

The railways were originally fed by three steam power stations of their own, situated at Cinkota, Soroksar and Budafok. The electric energy for the Szentendre line was supplied by the Palffyter tramway generating station. These power stations have now been shut down and the railways purchase electric energy from the Budapest municipal electric works. The primary current is 10 500-volt 50-cycle three-phase, and is transformed at the following substations into 1 000-1 200 volts D.C., or in some stations 600 volts D.C. :

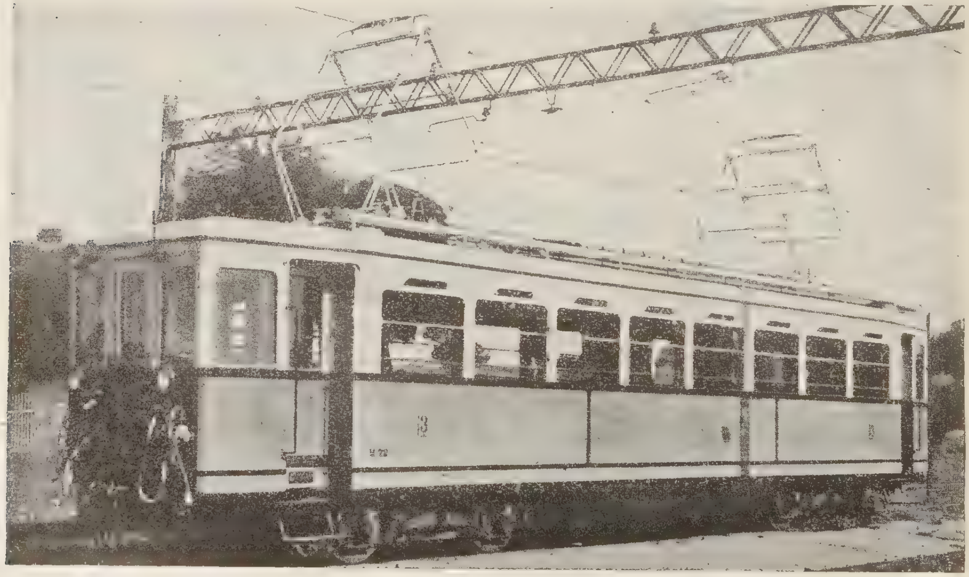


Fig. 2. — Standard-gauge 1 000-volt D.C. motor-coach on Budapest suburban lines.

Budafok :

2 rotary converters of 600 kw. each.
2 motor-generator sets of 200 and 250 kw.

Cinkota-Nagyitce :

1 mercury arc rectifier, 800 kw.
2 motor-generator sets of 450 kw. each.

Godollo :

1 mercury arc rectifier, 500 kw.
1 motor-generator set, 450 kw.

Filatorigat :

1 mercury arc rectifier, 800 kw.
2 motor-generator sets, 450 kw. each.

Pestszenterzsebet :

1 rotary converter, 600 kw.
2 rotary converters, 300 kw. each.
1 mercury arc rectifier, 500 kw.

The overhead conductor was one of the first catenary suspension and weight anchoring systems. The weights used for compensating the variations in length due to temperature change are arranged at distances of 1 000 to 1 200 m. (1 093 to 1 306 yds). The height of the trolley above rail level varies from 4.50 to 6.20 m. (14 ft. 9 in. to 20 ft.), and the distance between poles varies, on the straight, between 45 and 50 m. (49 and 55 yds).

The rolling stock consists of :

Locomotives :

11 two-axle, with multiple-unit control.	300 H.P.
10 two-axle, with hand-operated control.	280 H.P.
3 four-axle, with multiple-unit control.	440 H.P.

Motor Coaches :

19 two-axle, with multiple-unit control.	210 H.P.
21 two-axle, with multiple-unit control.	150 H.P.
3 four-axle, with multiple-unit control.	440 H.P.
66 two-axle, with hand-operated control	150 H.P.
6 two-axle, with hand-operated control	210 H.P.

Trailers :

76 two-axle (multiple-unit).
117 two-axle.
26 two-axle open (summer traffic).
6 four-axle (multiple-unit).
10 four-axle.

Both locomotives and motor coaches were built at Budapest by Ganz and have nose-suspended motors. The locomotives have a baggage compartment in the centre. The third class motor coaches have end doors and hinged platforms with side rails to permit of passage from one car to another. The bogies have outside plate frames and inverted laminated equalising springs on each side, connected to the laminated springs above the axleboxes.

The locomotives are fitted with standard buffing and drawgear and also with a special centre coupler with side links at a low height above the rail. The motor coaches are fitted with the second type of draw and buffing gear only.

Vac-Godollo line.

The Budapest-Vac-Godollo local electric railway, opened in 1911, can be regarded as an organic extension of the Budapest local electric system. It starts from Rakospalota-Ujpest, a suburb of Budapest ; it traverses a hilly country in a north-easterly direction to Veresegyhaza, 11 1/2 miles, where it divides, a 6 1/2-mile branch running south to Godollo and a 13 1/2-mile branch north to Vac, on the banks of the Danube. The line is single throughout. The total track length including station tracks amounts to 59.2 km. (36.7 miles) compared with the route mileage of 51.2 km. (31.9 miles). The steepest grade is 1 in 66, and the minimum curve 270 m. (890 ft.) radius.

The energy is supplied by the Ujpest power station of the Phoebus Electric Undertakings Co. Ltd. As long as 42-cycle energy was produced in this power station the railway was fed with 10 000-volt, 15-cycle single-phase current by means of three frequency converters of 1 000 kVA. output each. But when a change-over to 50-cycle in the power station generation was made the railway frequency was raised to 18.75 and the voltage to 12 000. The energy flows through three cables to the Rakospalota switching station and flows from here direct into the contact line and also along feeder cables to Veresegyhaza.

The overhead contact line is of the Siemens three-conductor suspension type. The messen-

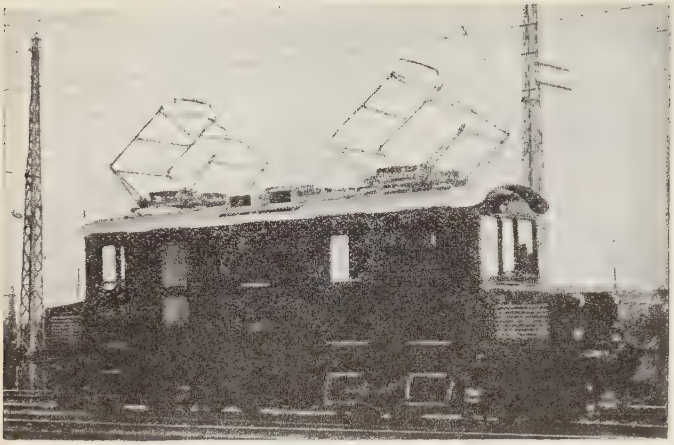


Fig. 3. — 440-H.P. locomotive for local traffic.

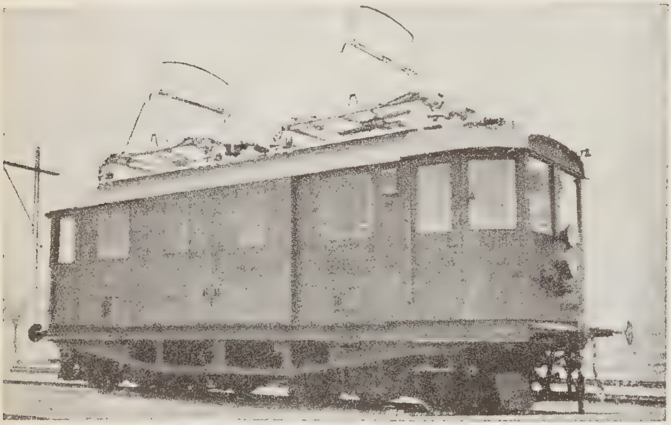


Fig. 4. — Single-phase two-motor locomotive on the Vac-Godollo line.

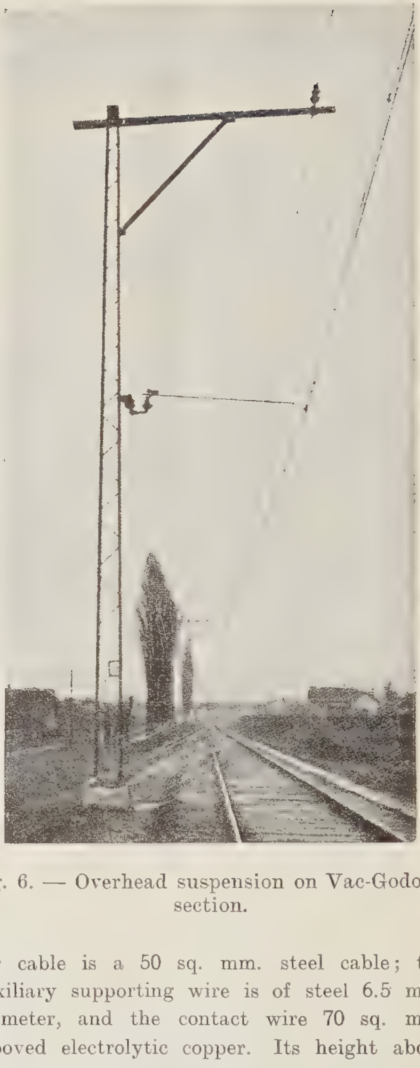


Fig. 6. — Overhead suspension on Vac-Godollo section.

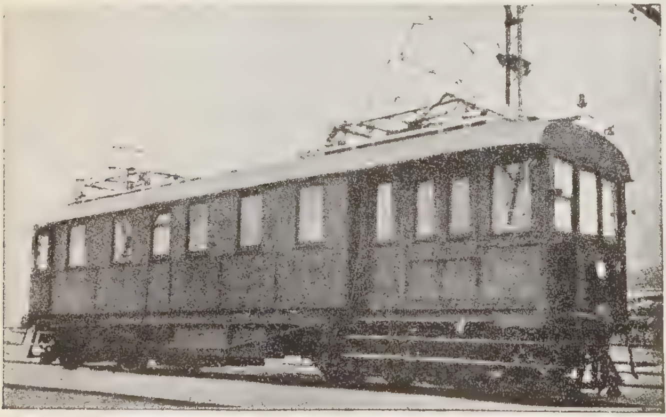


Fig. 5. — Motor-coach for local traffic between Budapest, Vac, and Godollo.

ger cable is a 50 sq. mm. steel cable; the auxiliary supporting wire is of steel 6.5 mm. diameter, and the contact wire 70 sq. mm. grooved electrolytic copper. Its height above rail level is 3.50 m. (18 ft.). The tension of the contact wire of the catenary system is maintained and adjusted at intervals of 1.5-2.0 km. (1 640-2 200 yds) by 400-kgr. (880 lb.) weights. The distance between the steel poles carrying the catenary system amounts to 100 m. (110 yds) on straight track and to 50 m. (55 yds) on the sharpest curves.

The traffic is handled by means of four

electric locomotives, 11 motor coaches and 18 trailers, having the characteristics shown below:

		Locomotives.	Motor coaches.
Type		B + B	1A + A1
Tare weight	Metr. (*Engl.*) tons	47 *(46.3)*	43 *(42.3)*
Axle load	Metr. (*Engl.*) tons	11.8 *(11.6)*	10.6 *(10.4)*
Maximum speed	Km. (*Miles*) p. h.	40 *(25)*	50 *(31)*
Trailing load over level track	Metr. (*Engl.*) tons	210 *(206.6)*	60 *(59)*
Trailing load up to 1 in 66	Metr. (*Engl.*) tons	160 *(157.5)*	40 *(39.4)*
Wheel diameter	mm. (*inches*)	800 *(31.5)*	850 *(33.5)*
Gear ratio		1 : 3.0	1 : 4.13
Transformer capacity		240 kVA.	180 kVA.

The double-bogie locomotives have one motor per bogie, and this drives both axles through the medium of a jackshaft and triangular rods. The underframe of the locomotive is of built-up steel sections, stiffened below the outside member by a light girder frame. The motor coaches have two nose-suspended motors, and both types of motive power units have two pantographs with bow collectors. Heating and lighting of the locomotives, motor coaches and trailers is effected electrically from the transformer.

Main line.

The electrification of the Budapest-Komarom section of the Budapest-Vienna main line was described in « The Railway Gazette » for July 7, 1933 (*). In September, 1934, the remaining section on to the Austrian frontier at Hegyeshalom was completed and a partial electric service inaugurated. By the spring of 1935, when 27 locomotives were in service, all the traffic was being hauled electrically except for a few local trains. The only main line service not worked electrically is the diesel railcar which runs once a day in each direction between Budapest and Vienna. The Ganz-Metro Vick locomotives have given most satisfactory performance, and the first two locomotives built up respective mileages of 168 000 and 190 000 miles during the initial 26 months of their lives.

[**656**. 254 (.44)]

2. — Wireless installations at the Rouen Docks, French State Railways.

(Le Génie Civil.)

The State Railways first started to install wireless in 1917. The aim was to repeat the signal indications on the locomotives by Hertzian waves; a radio conductor of the Branly type was used as a repeating relay, and the Augereau lock as receiver.

At that time the results were not good enough to justify the complicated equipment which was very difficult to tune up. It was decided to abandon the tests and use metal brushes on the engines with crocodiles inside the rails for cab signalling.

In 1919 and 1923, trials were made to communicate between trains in motion, but the results obtained were not satisfactory. These trials were carried out by various firms specialising in this class of work, and by the military authorities who used equipment of the aircraft type under the control of the late well known General Ferrié.

The failure of these tests was due solely to the fact that, at that period, wireless knowledge was insufficient for the delicate problems that arose in railway work. This is no longer the case, as radio-electric equipment has been vastly improved in recent years. As a result it has been possible to install in the docks, at Rouen, a system of wireless communication between the control station in the

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(*) See also *Bulletin of the Railway Congress*, August 1933, p. 753.

dock offices (left bank) and a number of shunting engines working on the dock lines, over a radius of 15 to 20 km. (9.3 to 12 miles).

Control station. This station is fitted with a transmitting aerial carried on a wood pylon 22 m. (72′ 2″) high. The receiving aerial is carried on the roof of the buildings 100 m. (328′) away, to avoid reaction between the two aerials. The two aerials consist of a tube 2 m. (6′ 6 3/4″) long, held in the vertical position by an insulated support. The 300-watt transmitter takes the power required from the local supply system.

Locomotive equipment. The equipment is contained in a strong cast aluminium case which is spring-supported inside a cast aluminium cupboard sealed up to prevent its being tampered with by incompetent people.

The transmitter consists of an oscillator, a symmetrical rectifier, and an amplifier with 95 % modulation.

Connection between the control cabin and the locomotive equipment is obtained by wireless telephone working in duplicate on a 6 to 8-metre wave length, these short waves being used to cut out parasitic oscillations.

The set is tuned up once for all, the messages are sent and received as with ordinary telephone.

The receiver is of the self-contained super-reaction type as used on aircraft, but considerably strengthened up.

The hand microphones and loud speakers are of a special railway type. The control box is extremely robust; the visual indicator provided prevents the enginemen making wrong movements.

The engine equipment consists of a 100-amp.-h. battery, a converter, tubular type transmitting and receiving aerials, arranged as follows :

When the observer occupies the driver's seat, the transmitter and its aerial are fitted on the right hand. The accumulators and the converters are fitted on the same side of the locomotive. The receiver and its aerial are fitted on the left side. The following equipment is fitted in the cab, handy for the driver :

1. the control box for sending and receiving messages;
2. the microphone;
3. the loud speaker above the driver's head.

The driver on starting has merely to turn the control knob to be able to send or receive a message. He can then talk to the control cabin without doing anything else except putting up the microphone to answer the question he receives by the loud speaker or to call up the control station.

This arrangment has improved the use of the shunting engines at the docks. The arrangment might be extended to trains on the open road, but this is not a practical proposition so far, as the problem is so much more difficult. The difficulties will no doubt be overcome in the near future.

The introduction of means of communication between a fixed station and any train will also improve the dispatching system very considerably.

H. M.

[621. 133.5 (.44)]

3. — Lemaître variable blast pipe.

Improved performance obtained by the use of Lemaître blast pipe on locomotives of the Nord Railway, France.

(*The Railway Gazette.*)

The accompanying drawings show the distinctive features of the Lemaître blast pipe, consisting of five convergent nozzles arranged symmetrically on a circle round a central nozzle, which is also convergent but of larger diameter and at a lower level. Variation of draught, to suit the requirements of operation, is obtained by raising or lowering a « spear » of ovoid form (fig. 2) to alter the steam passage in the central nozzle. It is claimed that this blast pipe, in conjunction with a special chimney of large diameter acting as diffuser, gives substantially better results than hitherto obtained. The subdivision of the steam flow provides a large surface of contact between the steam and the flue gases, while the form and high finish of the nozzles reduces back pressure to a minimum. The special shape and large dimensions of the chimney also contribute to the overall efficiency.

The advantages of simplicity in construction are combined with a wide range of variability. The dimensions of the Lemaître blast pipe and diffuser chimney as tried on Pacific locomotives of the series 3.1251-90 of the Nord Railway (France) are shown in figure 2. The sectional area of the steam passage is reducible from 243 to 150.5 cm² (37.7 to 23.3 sq. in.) by ten approximately equal decrements, and this wide and easy variability is particularly valuable in the working of the Nord Company's very fast and often heavy trains. Curves showing the smokebox depression as a function of the back-pressure on the exhaust are shown in figure 3 for three settings of the blast-pipe spear, viz. :

Notch 0, steam passage 243 cm² (37.7 sq. in.;
Notch 3, steam passage 215 cm² (33.3 sq. in.);
Notch 6, steam passage 183 cm² (28.4 sq. in.).

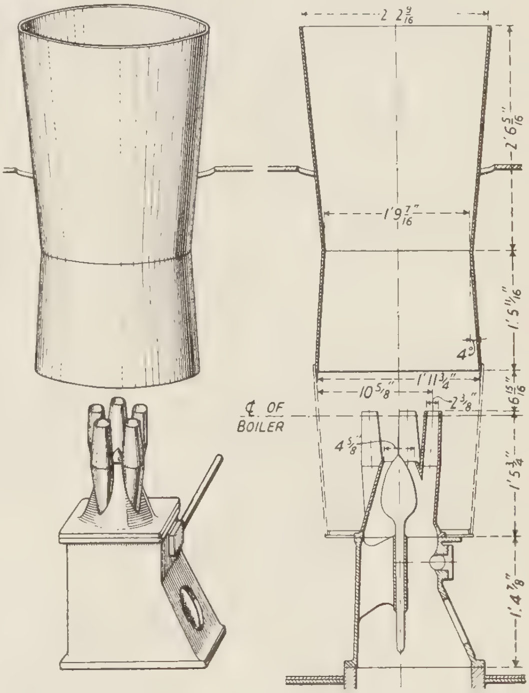

Fig. 1 (left). — General arrangement of Lemaître variable blast pipe and diffusing chimney. — Fig. 2 (right) showing regulating spear in central nozzle of Lemaître blast pipe.

These curves are plotted from measurements of the smokebox depression and steam back-pressure at the points indicated by *A*, *B*, respectively on the drawing.

From trials already completed, it appears that compared with the Nord blast pipe, the Lemaître type results in an increase in power which may exceed 200 H.P. for the same rate

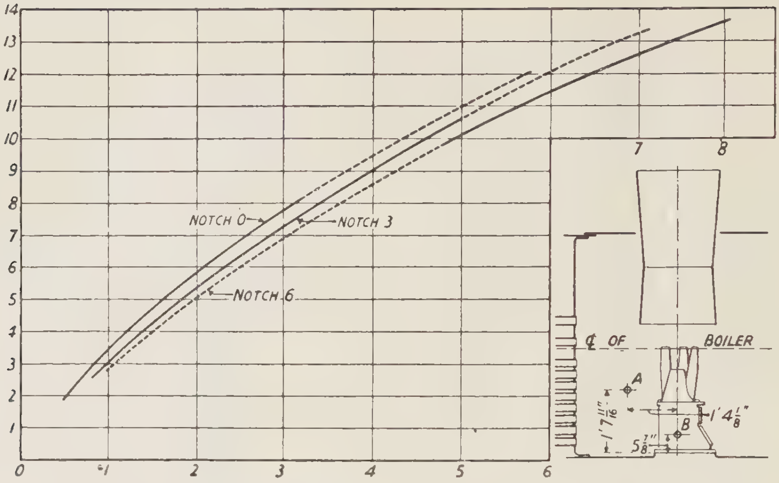

Fig. 3. — Smokebox vacuum and steam back-pressure with various adjustments of Lemaître blast pipe.

of combustion. Alternatively, there is an average saving of fuel amounting to 10 % for the same work done. Besides its applications on the Nord Railway of France and the Nord Belge, the Lemaître blast pipe is also being tried by the Belgian National Railways and the French State Railways.

Owing to the maximum speed limit of 75 m.p.h. imposed in France, hard uphill work is frequently called for, and it is under such conditions that a variable blast pipe shows to best advantage, for it enables the driver to modify the force of the blast near the end of the climb and so reduce the rate of steam generation.

[624. (06 (.43)]

4. — Second Congress of the International Bridges and Structures Association.

(Berlin : 1/11 October 1936).

The International Bridges and Structures Association, the Headquarters of which is at Zurich, is an association of the leading constructional experts of all countries.

The first Congress was held in Paris, in 1932, and the second is to be held in Berlin, this year, from the 1st to the 11th October. Nine meetings will be held, in the rooms of the Berlin Polytechnical School. The subjects to be discussed during the Congress are :

1. *Ductility of steel;*

2. *Stresses and safety factors in reinforced concrete structures;*

3. *Welding constructional practice and methods;*

4. *Present tendencies in the calculation and design of reinforced concrete bridges and structures;*

5. *Theoretical and experimental investigations of unusual points of rivetted or welded metal structures (joints, gussets, points at which concentrated loads act, etc.);*

6. *Concrete and reinforced concrete in waterworks practice;*

7. *Investigations into ground conditions.*

The programme also includes a number of formal meetings, as well as visits, excursions, etc.).

So as to make the Congress as truly international in character as possible, the whole of the documents will be issued in separate editions in the three official languages of the Congress (French, English and German). The discussions too will be translated into each of the official languages during each of the meetings.

The preliminary documents in connection with the Congress will be sent out at the beginning of September. The *Final Reports* of the Congress will appear early in 1937. The Association will publish, in September 1936, the 4th volume of its *Proceedings* which forms a supplement to the reports to the Congress.

Membership of the Congress including the subscription to the *preliminary documents* is 40 Swiss francs for the members of the Association and 60 Swiss francs for non-members. The subscription price to the Final Report is 15 Swiss francs.

Enquiries should be addressed to the International Bridge and Structures Association, Ecole Polytechnique Fédérale, Zurich, Switzerland.

NEW BOOKS AND PUBLICATIONS.

[351. 712 (.44)]

Recueil des Spécifications techniques et Cahiers des charges unifiés des Grands Réseaux des Chemins de fer français (*The French Main Line Railways' Standard specifications*). — New edition, revised up to November 1935. A collection bound in a loose-leaf holder. — 1935, Paris; Dunod, publisher, 92, rue Bonaparte. [Price : 185 francs (French currency. — The holder alone : 10 francs. — Separate specifications : 1, 2, 3, 4, 6, 7, 12 and 24 francs. — Table showing price of each specification sent free on application)].

We called our readers' attention in the September 1935 *Bulletin* to the new revised edition, published by Messrs. Dunod, of the standard specifications for metals and other materials used in the construction of equipment supplied to the French railways. Our readers will be interested to learn that some of these specifications have been revised and further new specifications issued up to November 1935. The out-of-date specifications can therefore be replaced by the latest issues and substituted for them in the loose-leaf holder.

R. D.

[625. 13 (.4) & 625. 3 (.4)]

BRUNNER (Pierre), Doctor of literature, Grenoble University. — **Les Chemins de fer aux prises avec la nature alpestre** (*Railways and their fight with nature in the Alps*). — A volume (10 × 6 1/2 inches) of 334 pages with many illustrations and inset plates. — 1935, Allier Père et Fils, Imprimeurs de l'Université, 26, Cours Jean-Jaurès, Grenoble, and A. Vogel, Kommissionsverlag, Winterthur.

In his introduction the author refers to the very old and ever increasing trade currents between Italy and Eastern, Central, and Western Europe. These currents had always been impeded by a formidable barrier, the Alps, which encircle the north of Italy from the Appenines to the Danube and the Dinaric range. Everything pointed to the necessity of building railways across the Alps, and led to the great Alpine railway tunnels being driven in succession.

On the other hand, the traffic in the Alpine valleys and from one valley to another gave rise to other problems and resulted in the construction of *internal* connecting lines between the great tunnels, then to branch terminal lines, or high level lines or spur lines starting from the great tunnels or the connecting lines, or from the periphery.

Finally, the growth of tourist traffic also led to the construction of *lines up the mountains,* beyond the valleys, to picturesque points, with special traction methods such as rack or cable.

The construction of all these lines encountered extremely serious obstacles in the Alps. The great differences in altitude and the steepness of the valleys involved heavy gradients, sharp curves, extensive bridgewrick and long tunnels. The nature of the ground made the work precarious. The severe climate with its avalanches and sudden floods meant the construction of many additional works and determined the locations of the lines. Suitable traction equipment, sufficiently flexible and sturdy had to be used, electric traction proving to be the best.

The difficulties of railway construction in the Alps and the way they have been overcome are dealt with in this book. The subject is a comprehensive one and has been dealt with from all aspects in the three hundred pages of the book. The author has obtained his information both directly from the railways and from bibliographical sources. The main chapters are :

I. *Development and present state of the Alpine railway system :* History. — Layout and density of the Alpine system.

II. *The Alpine railways and the configuration of the country.*

Rectrictions owing to the width of the mountains;

Rectrictions owing to their height;

Unfavourable configurations;

Favourable configurations.

III. *Alpine railways and the ground.*

Tunnels;

Open cuts;

Landslides onto the track;

Landslides under the track;

Suitabilbity of the Alpine rocks for buildings purposes.

IV. — *Alpine railways and the climate.*

Secondary factors—rain, wind rarefaction of the air;

Temperatures;

Snow.

V. — *Alpine mountain railways and waterways.*

Floods;

Torrents ;

River bridges;

Water power.

VI. — *Alpine railway working.*

Weights as determinated by the configuration;

Alpine railway operating technique;

Alpine railway train movements;

Road competition and railcars.

General conclusions.

Bibliography.

Additions and corrections.

⁂

The text contains 37 figures and maps illustrating many curves, loops, and bridges, and 15 inset drawings of different structures or of noteworthy sites.

The very large bibliography extends to 15 pages.

This summary suffices to show the fullness and interest of the information contained in this book, which, although it does not pretend to be a treatise on the construction of Alpine railways, will be read and referred to with much interest by constructional engineers.

Mr. BRUNNER has succeeded — and this is no small praise — in making a book of general interest one the expert will read with pleasure. R. D.

[**621**. 43]

Oil engines for road, rail and air transport (third edition). — A volume (8 × 5 1/2 inches) of 240 pages, with 240 illustrations. — Publishers : The Temple Press Limited, 5-17, Rosebery Avenue, London E. C. 1. (Price : 5 sh. net.)

This manual, of which this is the third edition, gives very full particulars of the different types of diesel engines used in motor vehicles, railcars, and aircraft. The previous editions dealt with the application of the diesel engine to road motor vehicles alone; this one gives full details of diesel engines used on railcars, and for this reason we call our readers' special attention to it.

Besides a brief summary of the working principles of the heavy oil engine and its main parts, the book describes most of the engines now on the market.

After dealing with the evolution of the petrol engine and the diesel engine, and describing the earliest application of the latter to road, rail and air services, the manual establishes a parallel between the working principles of these two main classes of engine. The question of combustion is dealt with specially under the three main methods of injection now in use : direct injection, pre-combustion chamber (ante-chamber), and separate air chamber.

The important part of the book consists of two descriptive lists of the types of engine in use, one for road motors and light railcars, and the other for railcars or higher-power locomotives used on the open road and for shunting purposes. The engines in each case are classified alphabetically under the makers' names, the first containing 55 types and the second 37, manufactured by makers throughout the world. The text in most cases is illustrated by photographs or diagrams. Each of these sections is completed by a table giving the main characteristics of the engines manufactured in Great Britain.

Engines for industrial and agricultural tractors and for aircraft are dealt with on the same lines.

The book then deals with the various types of fuel injection pumps, special metals and especially light alloys used in the engines, the design and construction of cylinders, pistons, piston rings, blowers for surpercharging, etc. Further chapters are devoted to the selection of fuels and lubricating oils, and specifications therefor, and to the costs of operating diesel-engined motor vehicles.

This up-to-date manual gives a large amount of information on the use of the diesel engine, especially on railcars. It also gives a clear picture of the present state of the diesel engine industry.

A. C.

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FÜLLES (Dr. Theo), Diplom.-Kaufmann. — **Die Eisenbahn-Personentariftheorien.** Ein lehrgeschichtlicher volks- und betriebswirtschaftlicher Abriss. (*Theories of passenger rates.* Historical summary of general and operating economics.) — A volume (9 × 6 inches) of XXII + 92 pages. — 1935, Cologne. Published by the « Institut für Verkehrswissenschaft an der Universität Köln », an der Bottmühle. (Price : 6.40 Rm. — Special price for Members of the above Institution : 4.80 Rm.)

In view of the many different works on railway passenger rates that have been published, a further book on the subject might appear superfluous. The rates structure of the different railways is, however, far from being based on any accepted theory, nor on any fully developed theory. Circumstances, especially during the last two decades, have caused the rates to be altered to meet each day's needs. The result has been numerous modifications, with many differentiations, and even peculiarities.

The author noticed, in the situation brought about by these alterations, such consequences and defects that he was led to investigate the question afresh. He subsequently enlarged the scope of his researches by attempting to devise a theoretical basis on which to build a rational system of rates.

The book contains much information, especially upon the work of German authors, some dating back to the beginning of the railways.

By means of these data, the author has been able to show how road transport rates were already based on factors which are still taken into account when fixing railway rates. He then considers the theories that have been admitted at different times, and shows there have been well marked epochs in the evolution of rates. He either gives the theories put forward by the principal authors he quotes, especially the mathematical ones, or summarises the fundamental theory and conclusions with particulars of the more or less satisfactory ways they have been applied. He also refers to the work done in connection with the calculation of the cost per unit carried and the relation of this cost to the rates.

The question of knowing how far scientific research can be used in building up a rates system is discussed in the course of the book and in the last chapter. The author considers it most desirable to be able to build on well established principles in times of crisis and transition, and to define rules which will maintain a happy balance between the standard and special rates.

E. M.